Macroeconomic perspective on water quality and quantity issues of relevance to the System of Environmental-Economic Accounting for Water (SEEAW)

Part A: Water Quality (Odense River Basin Denmark) - Deliverable 4.5 of EPI-WATER Project

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EPI WATER

Evaluating Economic Policy Instruments for Sustainable Water Management in Europe

WP4 EX-ANTE Case Studies

Macroeconomic perspective on water quality and quantity issues of relevance to the System of Environmental-Economic Accounting for Water (SEEAW)

PART A – Water Quality
(Odense River Basin, Denmark)

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Executive Summary

The present case-study of Odense river basin finds that a Water Supply Tax (EPI1) only provides a tiny contribution to improving water quality, whereas a Nitrogen-tax (EPI2) has potential to accomplish the stipulated river basin management planning targets for Odense Fjord in an economically attractive way.

Odense River Basin (ORB) is situated centrally in Denmark and the environmental issues and challenges faced here are in many ways typical for Denmark more generally, as well as for regions in EU Member States in north-western Europe with intensive agriculture (e.g. in Netherlands, Belgium, Germany, France, Ireland and UK).

Denmark is a country where farming occupies a greater share of the landscape than anywhere else in EU; 64% of land use is devoted to agriculture. Renowned for its 'butter and bacon' Denmark has fostered a farming model based on livestock production, with crops being cultivated largely for fodder purposes, and with large imports of wholesale fodder. Being a key player in the international food market, Denmark exports more than 75% of its pork production and has accounted for as much as 40% of global trade within this sector (OECD, 2003). There is a factor four from the Danish population of 5.5 million inhabitants to the number of pigs – more than 20 million being produced each year. Food exports have for a century been of key economic significance, although today being exceeded by exports of wind turbines and energy technology.

Not surprisingly the intensive agricultural production has put pressures on the environment in general and on water quality in particular. The use of mineral fertilizers was promoted with state subsidies as part of the farm modernization pursued following WWII. Within a relatively short time-span from the mid-1960's to the early 1980's, i.e. in about 15 years, leaching of excess nutrients to surface waters caused eutrophication events in the shallow Danish coastal waters to become a recurring phenomenon.

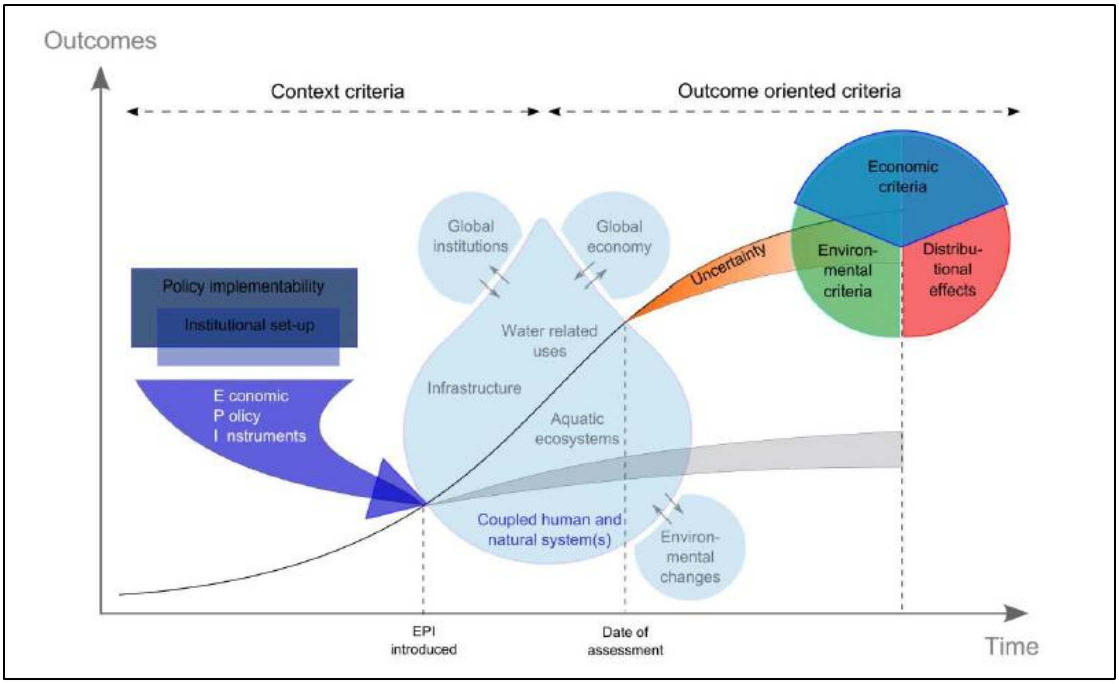
Starting from 1984 a series of plans and measures has been introduced to curb nutrient leaching. They have succeeded to improve the efficiency of fertilizer use and gradually to reduce leaching somewhat. Mineral fertilizers in particular can be substituted with organic fertilizers from livestock (such as manure) provided that the appropriate technologies are available (Andersen, 1994). The regulatory approaches favored by Denmark have aimed at prescribing specific cultivation methods and technologies, and have in addition introduced strict requirements for nutrient book keeping and annual reporting to the authorities. The prevailing approach has largely been the result of farmers being adverse to policy-instruments of economic nature (EPI's). While numerous suggestions to extend the tax on mineral fertilizers to farmers have been declined, as a paradox farmers have gradually admitted to regulations that include an obligation to use fertilizers at least 10% below the economically optimal level. This twist has in fact served to penalize crop growers rather than livestock farmers (despite leaching being higher per unit of organic fertilizer, see table 6.9 inside).

The catalogue of technological options is gradually being exhausted and the remedies which are available now to improve on water quality feature mainly a series of proposals that will serve to limit agricultural production, one way or the other. Buffer-strips along water courses, set-aside of wetlands and conversion of arable land to forests are in the pipeline, as the administration is searching for ways to accommodate compliance with requirements following from the EU's Water Framework Directive. Policy-making has become contentious and procedural issues have delayed Denmark's submission of River Basin Management Plans to the European Commission, while the remedies one way or the other are believed to become burdensome for taxpayers and farmers.

ORB has been used for more than a decade as a study site lab, where large amounts of data has been compiled to improve the scientific understanding of the nutrients flows in the environment. As a result ORB offers an interesting testing ground for considering different policy options, including what EPI's might contribute in the context of water quality challenges.

Despite 20 years' of nutrient control policy, surface waters in ORB remain of questionable quality. According to the draft ORB River Basin Management Plan (MOE, 2011) the estuary Odense Fjord (a semi-closed water body connected to the Belt Sea only through a relatively narrow outlet named 'Gabet' – the Gap) is presently classified to be of 'poor' water quality. Also 60 per cent of the water courses in the catchment are falling short of their quality targets, one reason being excessive abstractions. Of the relatively few ORB lakes one is presently of high quality, while 50 per cent are of poor or bad quality. A main reason for the poor score on surface water quality is nutrient leaching, with excess nitrogen today being the key concern. Phosphorus from traditional point sources to freshwaters has been reduced to a minimum, whereby the lakes are influenced mainly by historical P emissions.

Groundwater is the key source of drinking water, but well fields have been closed by water works due to nutrient contamination. About 17% of the ORB territory has been officially designated as nitrate sensitive zones with an obligation for additional protection measures against nutrient leaching. When considering the annual flow of nitrogen to Odense Fjord of 1735 ton (2009), 68% is believed to stem from agricultural activities.



In this case study we explore the potentials of two specific EPI's to address some of the above water quality management challenges, including the interplays between water quantity and water quality. We do so according to the assessment framework developed in WP2 and WP3 of EPI-WATER (see figure). We explore what environmental improvements can be obtained, but also what the potential costs will be and who in society that will be likely to have to shoulder these costs. The final step in our assessment is more conceptually oriented, and focuses on four key dimensions of EPI-application. These include the institutional background for the EPI's in question as well as the issue of policy implementability, and further address transaction costs and information uncertainty.

Denmark's Water Supply Tax for the domestic sector, which was introduced 20 years ago (1994) at a rate of €0.67/m^3, helps constrain water abstraction – and per capita water use in Odense has dropped with 40% over the past 20 years. This development helps increase water flows in Odense river and more significantly in the smaller adjoining water courses too. It also implies lower nitrogen concentrations in Odense river due to higher groundwater fluxes.

There is a relatively short residence time (7-9 days) for water volumes in Odense Fjord, but the abstracted water is being discharged well before river outlet, so in ORB there is no net impact ('flush effect') from the Water Supply Tax induced savings for water residence time in the Fjord. The circumstances nevertheless suggest a small impact on water quality. With less water being abstracted, the river and Fjord receive higher quantities of clean groundwater, rather than of sewage waters with nitrogen concentrations (of up to 8 mgN/l, the legally binding maximum).

Our analysis indicates that Odense river water flows were 2% lower before introduction of the Water Supply Tax. Regression analysis suggests that the tax can explain directly only 0.1-0.3% of the change. However, the Water Supply Tax was a component of a more comprehensive full-cost water pricing scheme which was introduced at the same time. When taking into account the entire scheme of full-cost water pricing to households, its impact amounts to between 0.5% and 1.5% of the change in Odense river water volume. Hereby it is reducing flows to sewage treatment plants with 1-2 million m^3 and the resulting potential relief on discharges amounts to 6-12 tN annually. Water demand has become less inelastic in tandem with water price increases and for a household sector where apartment blocks are largely without water meters, it can be hypothesized that extending metering would yield additional water savings with associated reliefs on N-flows.

The impact of the pricing approach on water quantity is far more significant in smaller watercourses close to abstractions. Simulations for Holmehave sub-catchment indicate that water flows in the smaller watercourse was 12% less before the full-cost water pricing scheme. While the Water Supply Tax can explain 1-2% of this change, depending on the regression model, the full-cost water pricing scheme as a whole is likely to be accounting for 5-10%. There are corresponding implications for nitrogen concentrations in Holmehave stream, and as a branch of Odense river the gross environmental implications for surface water quality are included in the above assessment for the Fjord nitrogen load. To the extent that the nitrogen concentrations echo ammonium, there are positive implications for fish life and biodiversity of the improved water quality that follows from improved flows.

Future scenarios have been modeled to take into account projections for population growth and increases in economic activities. These projections suggest that the Water Supply Tax will need to be increased to keep household water demand in check, considering that there is very little space for increasing water abstraction without implications for water flows in ORB water courses. The 'Economy First' scenario, with 2% annual economic growth and a population increasing in line with forecasts from Statistics Denmark, suggests water flows in Odense river will reduce with 6%. The simulations presented here indicate that the Water Supply Tax may have to be doubled to reduce water consumption per household and maintain the overall balance in ORB, allowing for stable water flows. Higher precipitation as a result of climate change may influence these implications however.

Denmark's Nitrogen Fertilizer Tax, which was introduced 15 years ago (1998) at a rate of €0.67/kgN, does not apply to the use of mineral fertilizers in agriculture. The use of mineral fertilizers on arable land has been considerably reduced from its peak in the mid-1980's, dropping from 145 kg N/ha in 1984 to 71 kgN/ha in 2012, with only a modest trend of decline over the past decade (Statistics Denmark, 2013). A Treasury headed working group (MOT, 2003) considered to abolish the exemption from the Nitrogen Fertilizer Tax for farmers and presented a comprehensive analysis, which included several alternatives, including a nutrient-loss taxation scheme comparable to the previous Dutch MINAS approach (cf. Mallia and Wright, 2004). Despite this effort contributions from economic policy instruments have been largely ignored during the recent river basin management planning process that has focused on land-use specific measures, many of which are involving support schemes.

With the present analysis we explore what a nitrogen taxation scheme might contribute towards the river basin management planning targets for ORB. We introduce two EPI scenarios and explore their implications for nitrogen flows with an impact pathway analysis that begins with an ORB-specific farm model and tracks the transport and dispersion of nitrogen to surface waters with resulting implications for annual average sight-depth and eutrophication (Rabl and Peuportier, 1995; Andersen et. al., 2011). The economic viability of the EPI scenarios is further considered with an appraisal of the environmental consequences within a conventional framework of costs and benefits. In doing so we assume that nitrogen taxation is introduced in a revenue-neutral fashion, replacing other taxation specific to farmers, such as the land use tax. Providing a compensating relief via the land use tax allows revenues to be returned without distorting incentives.

The tax rates for the EPI-scenarios in question amount to €1.85 (T1) and €4.54 (T2) per kg N in mineral fertilizers. While a T2 rate is practically prohibitive to the use of mineral fertilizers, T1 helps reduce their use by more than 50%.

We find that T2 could help accomplish a Fjord classification of 'high' ecological quality, whereas T1 would be sufficient to meet the stipulated river basin management planning classification of 'good' ecological quality for Odense Fjord.

In considering the benefits of the two scenarios both use values of surface water quality as well as related pathways of nitrogen (ammonia, GHG and drinking water) and their end impacts are taken into account. We find considerable benefits for both scenarios ranging from €4.8 to €7.6 million annually, despite a relatively timid valuation approach focusing mainly on use values. Most benefits are related to health-impacts of ancillary nitrogen effects, rather than to improvements in surface water quality *per se*. These findings suggest that improved water quality should be seen as a side-effect of a wider nitrogen reduction programme, rather than a stand-alone measure.

The costs to farmers are quite different in the two scenarios. As T2 becomes a prohibitive tax there is no revenue available for compensating farmers and as a result T2 becomes rather costly - €12 million. In contrast the cost of T1 to farmers, according to the ORB area model, is estimated to be €4.1 million annually, which compares favorably with benefits of €4.8 million, suggesting a net gain.

With T1 the nitrogen load on Odense Fjord would be reduced with more than 600 tons from the present level. The aggregate cost of accomplishing a comparable reduction with non-EPI measures has previously been estimated at €5.8 million annually (MOE, 2007:70), 40 per cent more than with T1. The previous analysis is a bottom-up land-use focused approach and comparing it directly with our top-down modeling approach is not straightforward. Nevertheless the indication that an EPI-based approach offers a potential for cost savings is in line with what we would expect on basis of economic theory[1].

The main reason for the superiority of economic instruments is that they provide sound incentives for all polluters to search for the most efficient abatement options. In the ORB-model 2000 farms have been modeled individually to optimize their yield functions for crops according to the cost of Nitrogen-fertilizer, while remaining within the boundaries for crop diversity related to their basic specialization. The options that the model can identify for farmers come out favorably

[1] Findings from the above mentioned working group suggests that the EPI costs could be further reduced with a nitrogen taxation scheme that addresses all N-input, also from fodder, and provides a refund for product-embodied N (MOT, 2003). This would effectively be a tax on N-loss rather than on fertilizer-N only.

economically as compared to the changes in land use that can be envisaged by a 'central planner'. By recycling revenues for a lowering of land use taxation, the scheme will not impose an additional tax burden on farmers. Still, the scheme will induce a net loss in income, but it can apparently be compensated at less cost than with a land-use regulation oriented approach.

Institutionally there is little scope for a regional fertilizer tax applying only in ORB and it follows from Denmark's Constitution that taxes can only be imposed by approval in Parliament. The same condition applies for the water supply tax, implying that tax rates cannot be tuned to ORB circumstances only. The universal character of economic instruments is to some extent at odds with the often site-specific character of environmental burdens, but to the extent that ORB is a catchment with quite average conditions applying more generally in Denmark, the study here is suggestive for what might be a feasible approach to management of surface water quality with EPI's and river basin management planning might tune targets for the various surface waters to the cost-effective capacity of a national fertilizer tax.

Implementability hinges first of all on stakeholder involvement and acceptance, in particular relating to farmers. The economic burdens of the present command-and-control approach of water regulations are becoming widely acknowledged among farmers and there is a demand for more flexibility, which may in fact work out in support of EPI-based approaches to which farmers conventionally have been skeptical. The transaction costs have been carefully analysed and are practically insignificant, partly because legislation and administration is already in operation for both EPI's. Adjustments of tax rates and/or removal of exemptions would only improve the efficiency of EPI management. Data used for the present analysis has been compiled over many years of experience with the Water Supply Tax and with detailed fertilizer book-keeping, which has provided a detailed basis for the assessment and helps limit uncertainties.

Water accounting according to the framework developed by UN is a tool that can support further and more detailed analysis of the economic and environmental implications of policy measures, including with EPI's. Water accounting principles clarify how water use is linked to different economic sectors and thus allows linkage to an appropriate input-output model of the economy (UNSD, 2003).

> "7.30. Quality accounting is useful for following the evolution of the water quality and it furnishes an indication of the efficiency of the measures taken to protect or improve the state of bodies of water."

This quote from the recently revised guidelines on water accounting takes notice that there is yet no best international practice with regard to water quality accounts (UNSD, 2012).

The above analysis of EPI's demonstrate that non-point source pollution can be assigned monetary unit values according to the same impact pathway methodology that has been applied by European institutions in the field of air pollution and which allows for monetary valuation with high spatial resolution (European Commission, 2005; Rabl and Peuportier, 1995). The analysis also illustrates, with appropriate modeling tools, how it is feasible to disentangle quality changes in water bodies and to link these with the relevant economic sectors causing these quality changes.

Water accounting aims to link flows with stocks – with regard to water quality this implies linking flows of emissions to changes in the quality of water bodies. We have illustrated here only for one pollutant, nitrogen, how this can be done, but obviously it should be feasible to extend this exercise to additional key pollutants. The knowledge base for assigning monetary values to the various emissions according to their site-specific impact has been developing gradually in various research projects and must be expected to consolidate in the years to come.

It remains a challenge, however, to assign the water bodies *per se* monetary values. The aquatic environment performs several economic functions that need to be taken into account. Besides the amenity value, there is principal value in terms of a) life-support b) natural resource and c) emission sink. EPI-WATER WP5 will further address this and other challenges related to water accounting.

Seden Strand and Odense Fjord viewed facing north. Odense Canal is seen on the left of the photograph, and the mouth of the River Odense in Seden Strand is seen on the lower left. Photo: Jan Kofod Winther.

The landscape in Odense River Basin (ORB) has been formed at the end of the last glacial period. Ridges are found at the hilltops of Vissenbjerg and around Ringe town in mid-Funen. Among these the Odense river valley depression stretches from south-west towards north-east, reaching a low-lying, flat area around Odense Fjord. West of the Fjord is *a flat terrain with higher altitude. The far southern catchment edge features a ridge named the 'Alps of Funen' including the renowned Svanninge Hills. To their north is a lower, partly hilly area, with the largest lake of Funen, Arreskov lake. Having its offspring here, Odense river traverses the entire catchment* towards *northwest, through the valley, to its outlet in Odense Fjord (translated from MOE, 2011:66).*

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1. Introduction

How to capture water quality aspects of water management within environmental accounts has been addressed in the recent SEEA-publication, the System of Environmental-Economic Accounting for Water (UNSD, 2012). These guidelines represent useful progress in clarifying water accounting principles more generally, as well as specifically with regard to water quality aspects, following almost a decade-long process of discussions in the London Group of Environmental Accounting and elsewhere (UNSD, 2003).

Although water quantity issues seem to be more pressing in many countries, challenges related to water quality are often equally important to the actual use value of water. For this reason it is desirable to treat water quality issues within the same accounting framework as water quantity issues. Treating water quantity and water quality as interrelated issues reflects the realities in management of the full water cycle.

Despite high policy relevance the water accounting guidelines remain experimental with regard to water quality because an internationally best practice has not emerged (UNSD, 2012:iii). For the monetary aspects relevant for macro-economic analysis, the guidelines provide a review of state-of-the-art valuation techniques but without addressing water quality aspects specifically.

In this catchment-based case study on economic policy instruments (EPI's) related to water quality management, we explore not only the possible significance of EPI's for quantity-quality interrelations but also how specific quality attributes of the good water can be assigned monetary unit values, hence enabling environmental economic analysis and a hopefully more consistent approach in water management of quantity-quality trade-offs.

With our approach we aim to contribute to improve water accounting, and the findings from our analysis of EPI's are in turn considered under the perspective of the possible linkages of water accounting frameworks to more conventional macro-economic modelling for the purposes of policy analysis (as will be further explored in WP5 of EPI-WATER).

2 EPI Baseline

2.1 Baseline and key assumptions

Due to the choice and availability of the modelling tools and data, the baseline conditions, drivers of change, and time horizon vary according to the EPI under analysis.

For the case of the Danish Water Supply Tax (EPI1), we consider both past, present and future conditions, under several alternative scenarios. As a first step, we investigate an alternative scenario assuming that the existing water supply tax had not been introduced. Our aim is to estimate the water savings achieved with the introduction of the tax as well as the effect of the tax on water quality. Moreover, we explore tax scenarios assuming an increase in the tax rate, starting from the 2010 rate of €0.67/m^3 (5 DKK).

We take into account two main drivers of change: expected future water withdrawal and population increase. We estimate future trends of these parameters based on scenarios developed in the SCENES EU-project (SCENES, 2006-2010) and on basis of the Shared Socioeconomic Pathways (SSP) database (SSP, 2012), cf. table 2.1. The projected population growth of the "Economy First" scenario is largely similar to the official population projection from Statistics Denmark.

SCENES SCENARIO		SSP SCENARIO
Ecf - Economy First	≈	SSP 5: Conventional Development
FoE - Fortress Europe	≈	SSP 3 - Fragmentation
PoR - Policy Rules	≈	SSP 2 - Middle of the Road
SuE - Sustainability Eventually	≈	SSP1 - Sustainability

Table 2.1. SCENES and SSP scenarios compared.

For the case of the Danish nitrogen tax (EPI2) we consider a baseline scenario (business as usual, BAU) assuming the current market price of mineral fertilizer (€0.83 per kg N), in order to model two scenarios:

- a tax on mineral fertilizer increasing the price to €2.68 per kg N (20 DKK)
- a tax on mineral fertilizer increasing the price to €5.37 per kg N (40 DKK)

These tax scenarios have been chosen to explore how the N load reduction that is necessary to achieve a 'good' ecological status of the Odense fjord, as stipulated in the draft river basin management planning under the Water Framework Directive (WFD), might be obtained. A tax rate of €1.85/kg N is believed to approximate the average external costs of nitrogen application, when considering available estimates from previous research. However, some areas are classified as nitrogen sensitive and would require a higher tax rate for the appropriate level of protection, for this reason a higher tax rate (€4.53) on mineral fertilizer is also explored.

The most important drivers of change for EPI2 are considered to be the future changes in livestock numbers and land use changes. Modelling parameters such as crop distribution and yield functions are expected to change in time, e.g. if climate change projections are taken into account.

2.2 Reference policy instruments

Denmark introduced with its Environmental Tax Reforms (ETR) in the 1990's several EPI's relevant for water management:

- A *Water supply tax*, the objective of which is demand management. It protects groundwater via reduced water consumption (ECOTEC, 2001). The rate has been for many years €0.67/m^3 (5 DKK) of piped water supply. The tax applies to water supplied to households and public buildings, but not to the agricultural and industrial sector. The tax is liable for abstracted water at water works, public as well as private, which then pass the tax on to their customers. The water works are liable for 90% of their abstraction, so the scheme allows for leakages of up to 10% of abstracted water. In practice this is a strong incentive for surveillance and monitoring of the water pipes, and leakages have come down from the level of 30-40% prevailing before in Denmark (as is still the case in many urban areas across Europe). In 2012 the tax rate was adjusted to €0.73/ m^3 (5.46 DKK) with effect from 2015.
- A *Wastewater tax*, also introduced in 1993 as part of the "green tax reform", and fully effective since 1998. It applies to discharges of organic material (BOD - biological oxygen demand), N and P from point sources: mainly wastewater treatment plants, industries, and dwellings not connected to the sewerage network. Some significantly pollutant activities are exempt and pay only a minor percentage of the tax (3% for fish processing, cellulose and sugar beet industries). The standard rate of the tax is of €1.48/kg BOD (11 DKK); €2.69/kg N (20 DKK); €14.78/kg P (110 DKK).
- A *Phosphorus tax*, which applies to agriculture and aims at reducing the excess phosphorus (2009 reduction target of 25%) with a rate of €0.53/kg P in feed (4 DKK; intended as total mineral phosphorus) and through general improvement of the phosphorus balance (Miljøstyrelsen, 2000).
- A *Nitrogen tax* for mineral fertilizer sold in small quantities and with a rate of €0.67 /kg N (5 DKK). The legislation (Law no 418/1998) has been prepared so that it could be applied also to agriculture, should they not deliver on national reduction targets for nitrogen leaching, but presently mineral fertilizers used for farming purposes are exempt from the tax.

The above mentioned taxes are subject to 25% VAT (Value Added Tax).

Tax payers have been compensated for these water-related EPI's – and other ETR-taxes - with a revenue-neutral reduction in payroll taxes (mainly employers' social security contributions but also income taxes) (see Hansen, 1999; Miljøstyrelsen, 2000).

3 Key problems and challenges in ORB

3.1 Introduction

The Odense River Basin (ORB) is among the most well studied water environments in Denmark. It includes the Odense River, numerous small lakes, and the shallow Odense Fjord.

In ORB catchment land use (1,190 km²) cultivation of cereals, greenhouse gardening and livestock (mainly pig farming) are principal economic activities, whereas the city of Odense is the biggest urban area with 187,000 inhabitants (2/3 of the entire ORB population).

As a consequence of human pressures and man-made modifications of the natural environment, which occurred in the last century, the natural properties of the aquatic system of ORB have been partly lost. The natural self-cleansing ability and remediation capacity of the Odense Fjord and of the Odense River have been greatly reduced with implications for the maintenance of ecological water quality. Presently, several ORB water bodies fail to meet their environmental objectives (MOE, 2007).

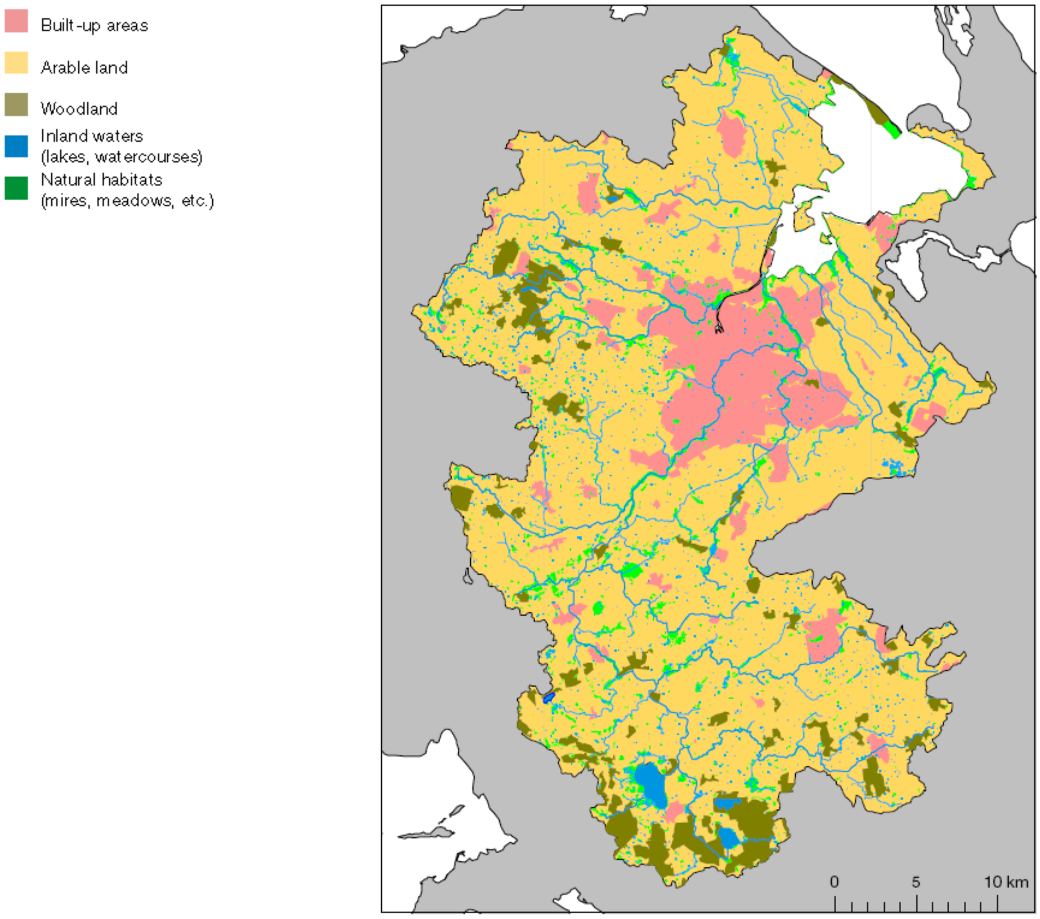


Figure 3.1: Land use of Odense River Basin (subcatchments Nærå Strand, Dalby Bugt, Lillestrand and Bælthavet not available).

In ORB, surface water quality is today affected by diffuse nitrogen (N) and phosphorus (P) loads from diffuse (agriculture) and point sources (sewage treatment plants).
Moreover, groundwater quality is affected by reduced infiltration of rainwater, excess abstraction, and leaching of contaminants. These issues are of particular concern given that groundwater is the main source of water supply in Denmark (99% of total supply).

The main challenges concerning water management in ORB are therefore the reduction of nutrient load and the avoidance of excessive groundwater abstraction. Moreover future water management must be planned to meet the objectives of the Water Framework Directive (WFD) and synchronized with the Natura 2000 planning to achieve good environmental status for both aquatic and terrestrial habitats.

3.2 Surface waters

Water courses: There are 728 km of primary water courses in ORB (see figure 3.2). Especially the smaller water courses are suffering from poor physical conditions and excess water abstraction. There is a need for policy instruments to improve the water flow as a tool to meet quality objectives.

The requirements stipulate that water abstraction should not reduce water flows by more than 5 per cent for water courses classified with 'high' ecological quality criteria. 10-25 per cent reductions (in relation to original median minimum flow) can be allowed for water courses targeted for 'good' ecological water quality. 290 km of ORB water courses (40%) are not meeting their targets in this respect.

Overall 59% of water courses do not meet the quality criteria established with the draft ORB River basin management planning (MOE, 2011:167). Projections show that this situation will not change fundamentally with current policies.

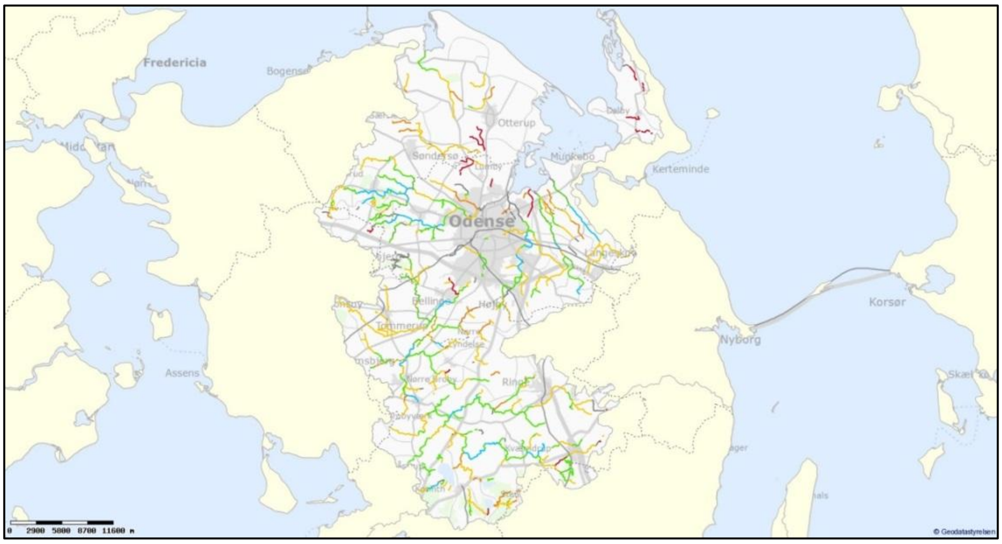


Figure 3.2: ORB primary water courses with stipulated quality classification.

Lakes: There are more than 3000 lakes in the catchment, but the larger ones (>5 hectare) tend to be located upstream towards the southern border, making them less exposed to nutrient leaching. Of 16 larger lakes (see figure 3.3) only one reaches 'high' ecological quality, while 50% are classified being of 'poor' or 'bad' quality. The excess phosphorous stems mainly from internal pressures, e.g.

deposited/historical emissions – and birds! Targets aim for reaching ‘good’ ecological status, while 6 lakes are prioritised for action to reduce P in the first plan period.

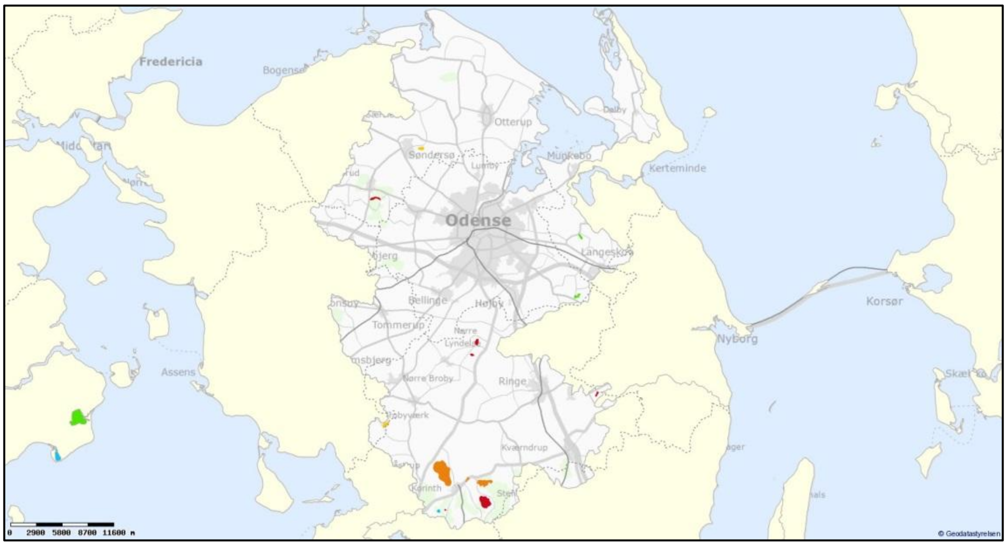


Figure 3.3: ORB primary lakes (>5 ha.) with stipulated quality classification.

<u>Coastal areas</u>: The small Odense Fjord (68 km²) acts as an intermediary between freshwater runoff and the northern Belt Sea, and is subject to many influences. The current state of the water body is overall regarded as poor not least due to a high influx of nutrients. There is a chronic state of eutrophication in the inner part of the Fjord (average depth <1m) and seasonally in the outer part (47 km²).

The draft ORB River basin management planning aims for attaining ‘good’ ecological conditions in Odense Fjord. Historical data allows for determining the reference conditions with eelgrass as indicator. The Fjord has also been designated a Habitat area under the EU Directive (except the outer Fjord’s eastern part).

Nutrient transport to Odense Fjord has been reduced significantly since the late 1980’s from about 3000 ton N annually to 1735 ton N in 2009, i.e. with 42%. The draft River basin management planning aims for a further reduction to 1340 ton N, i.e. with 400 ton N. About 1/3 of this reduction is expected from policies-in-pipeline, but the majority will require new initiatives.

Deliberations at the national level in Denmark are currently expected to result in further reduction requirements with implications also for Odense Fjord. This could imply additionally 250 tons N being targeted for reduction, provided that cost-effective approaches can be identified, i.e. to 1100 tons. It has been stipulated that N-flows need to be reduced to a maximum of only 600 ton N annually to attain the desired ecological status (Kerteminde kommune, u.å.).

3.3 Ground- and drinking water

There are 12 regional aquifers with groundwater in addition to catchment-wide general groundwater abundance in the terrain (see figure 3.4). These aquifers are important sources for drinking water supply, which local water works are abstracting from altogether 85 well fields.

Surface waters are not in use for water supply; it relies exclusively on groundwater, being largely untreated. Abstractions by industry and for irrigation (greenhouses) make up 5% and 10% respectively of total water withdrawal, the majority being abstracted for domestic use (households, business and public entities).

At catchment level water abstraction has been found to balance with availability, although abstraction is skewed towards aquifers near the urban area. Despite a moderate population density (52/km^2), 4 aquifers are being exploited well beyond the criteria for recharging. The overexploited aquifers account for 15 million m3 of the total annual abstraction of 26 million m3 – with 8-10 million m3 in excess abstraction.

The aquifers feed lakes and watercourses and contribute importantly to species and biodiversity. 255 habitat areas within Natura-2000 designated areas in ORB are dependent on water quantity.

Groundwater quality is vulnerable to nitrate leaching. 17% of the total catchment area has, according to national legislation, been designated as nitrate sensitive zones due to concerns with aquifers (see figure 3.5). Arable land in nitrate sensitive zones is subject to precautionary requirements with regard to fertilizer and manure use. Specific nitrate management plans have been developed in certain districts only (see figure 3.6).

The draft ORB River basin management planning is short of measures to address excess abstraction of aquifers and postpones action. As for the nitrate quality criteria, reference is made only to the EU cut-off value for drinking water (50 mgN/l), whereas previous regional planning was based on the former EU guide value (25 mgN/l). Groundwater quality protection is seen more as following from national plans and priorities.

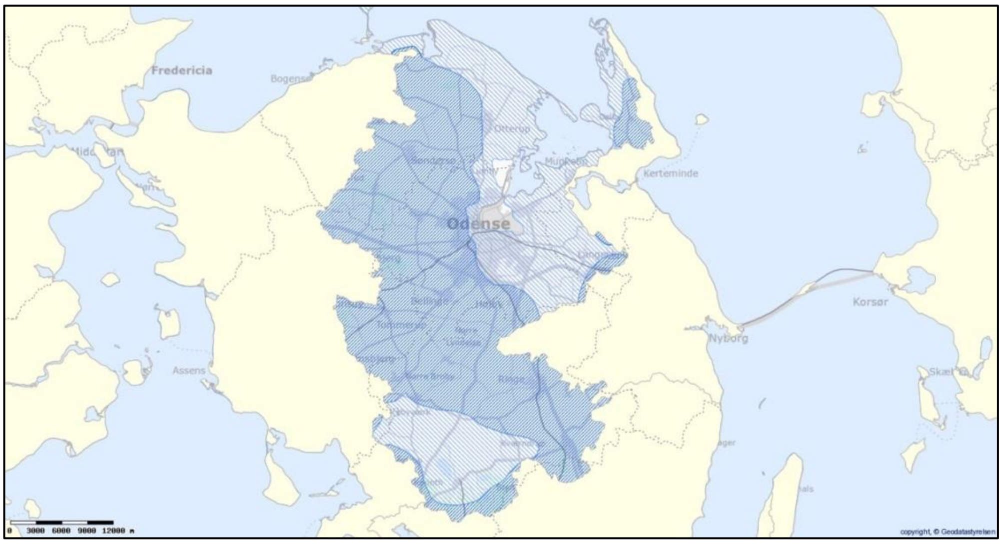


Figure 3.4: ORB areas with drinking water relevance of special and general interest.

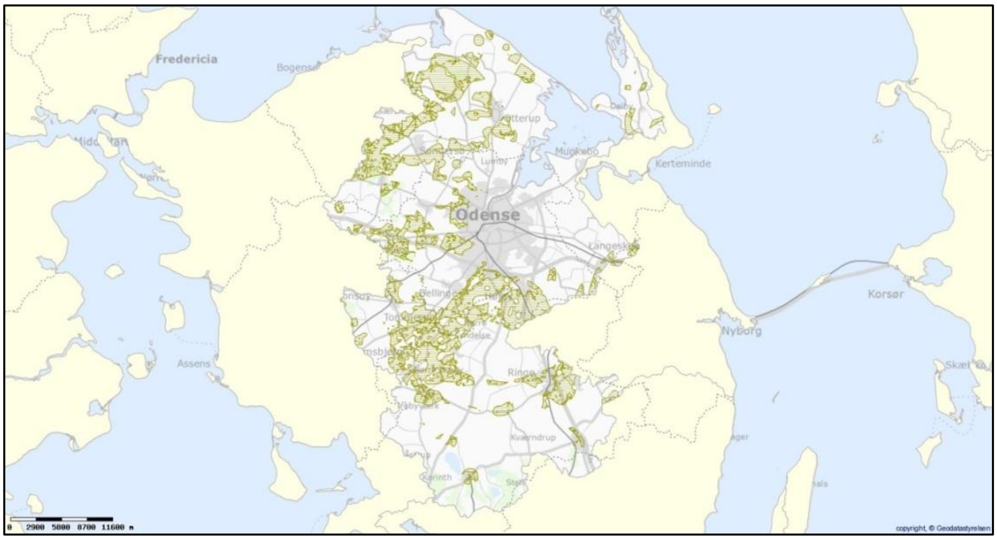


Figure 3.5: ORB designated nitrate sensitive zones.

Figure 3.6: ORB nitrate sensitive zones with specific management plans.

3.4 Key drivers and implications

Pressures on water resources have levelled off in quantitative terms over the past decades. Since 1983 water demand in Odense has seen a reduction of 40%, despite a population increase of about 15% in the same period. The decrease in water consumption reflects several influences, including the transformation from a manufacturing economy to one based more on services and trade. However, the tripling in the real effective water price must also be expected to have played a role as we will be exploring below. Besides environmental taxes related to water, Denmark's full-cost approach to water service pricing for water supply and municipal waste water is a key factor. Per capita consumption in households is now estimated to be 110 litre/day.

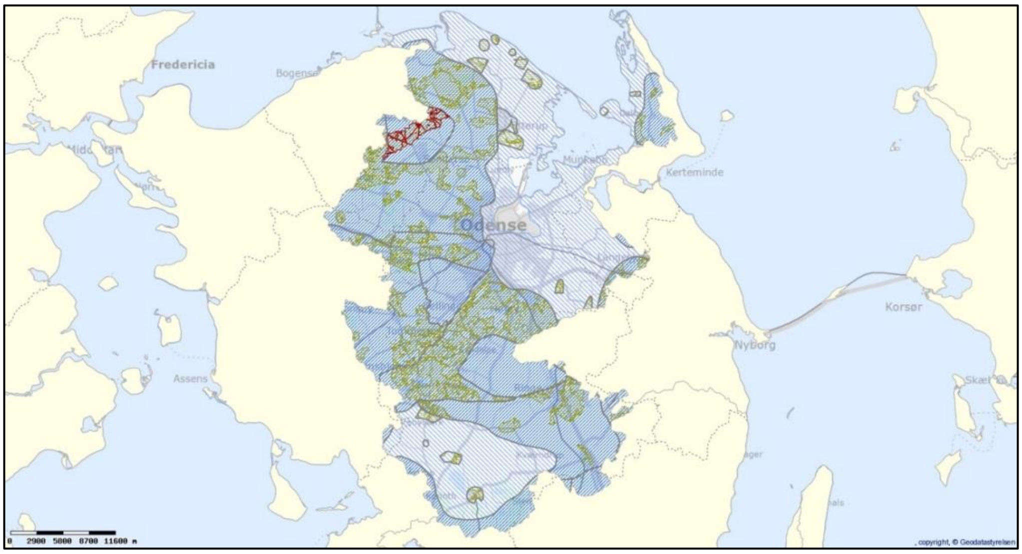


Figure 3.7: ORB groundwater aquifers with areas of drinking water interest and nitrate sensitive zones, including zones with management plans.

The leaching of nitrogen and phosphorous to groundwater and surface waters has been subject to regulation in Denmark since the mid-1980's. The Plan for the Aquatic Environment agreed in 1986 by the Danish Parliament aimed at a 50% reduction in leaching (Andersen og Hansen, 1991), and subsequent amendments to the plan and efforts to accomplish targets have involved extensive technical analysis.

Despite significant reductions in fertilizer use and complicated schemes to regulate the use of animal manure, farming remains a key factor in the pollution with nutrients. In ORB 68% of nitrogen leaching is estimated to come from farming activities (MOE 2011:96).

Livestock farming is an important sector in Denmark, more than 75% of its pork production is exported and Denmark accounts for 40% of the pork meat traded on the world market (OECD, 2003; Andersen, 2003). Dairy production is another hallmark of Danish farming. With an average concentration of 0.9 livestock units per hectare the ORB catchment is a region of medium intensity regarding animal husbandry (see figure 2.4 or equivalently figure 3.8).

Still, questions continue to be raised over the efficiency of protecting water as compared to the competitiveness of animal husbandry. Environmental experts have been largely unable to provide an effective formula to address the socio-economic concerns, which over the past years have become more pronounced. Still, as a result of the financial crisis the livestock production in ORB dropped with 15 per cent from 2007-2012, providing a relief in ORB nitrogen application (Statsforvaltningen, 2013).

Preparations for Denmark's 'Green growth' plan (Government, 2009) reflected these dilemmas. While biological expertise suggested that an additional national reduction in nitrogen leaching of 30,000 tons of nitrogen (national level) would be required to comply with WFD, in particular for the vulnerable Fjords, the government in the end opted for a more modest reduction target of 9,000 tons N. Further analysis is in preparation to assess the efficiency of an additional 10,000 tons reduction.

The proposed EPI1 and EPI2 can be regarded as suitable to address some of the key concerns with regard to ORB and ORB river basin management planning.

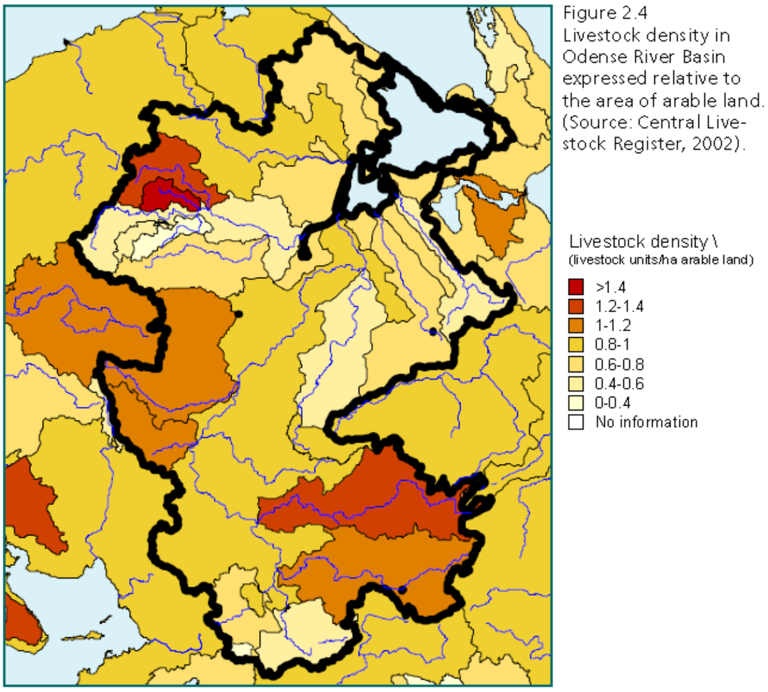


Figure 3.8: Livestock density in ORB.

4 Policy design

4.1 Policy Design EPI1

The first EPI (EPI1) is a modification of the existing Danish water supply tax on water abstraction.

The existing Danish water supply tax has some weaknesses and limitations (ECOTEC, 2001). For example, the agricultural sector and most of the industrial sector are exempted from the tax, which therefore does not promote water-use efficiency in agricultural and industrial activities. Still, most of the water abstracted in ORB is used by households for domestic purposes (85%), and water savings can thus be achieved also when focusing on reducing domestic water demand.

Although in the past domestic water demand in ORB decreased significantly (DST, 2012), it is unclear how reductions could be attributed to the price and tax increases. The improvements in water quality of surface waters and groundwater as a result of the induced reduction in groundwater abstraction have so far not been considered, as EPI's are being neglected in the river basin management planning process.

The purpose of the analysis is to investigate the effect of the water supply tax from:

- an economic perspective: by studying the elasticity of water demand with respect to the price of water,
- an environmental perspective: by studying the complex relationship between ground/surface water quality and quantity of water abstraction in the basin.

Based on this preliminary analysis, scenarios assuming that the tax on water abstraction is modified (e.g. increased) are analysed (EPI1).

Higher water prices, due to the introduction of EPI1, can be expected to decrease water demand of households and consequently water abstraction, thus reducing the anthropogenic pressure on groundwater aquifers. The tax is not only expected to have a direct effect on water quantity; the hypothesis is that water quality of both groundwater and surface water bodies should improve indirectly, as the availability of clean water volume is increased with higher flows to aquifers and water courses. The future improvements in water quality achievable with the implementation of EPI1 hence can be estimated quantitatively and linked to EPI1.

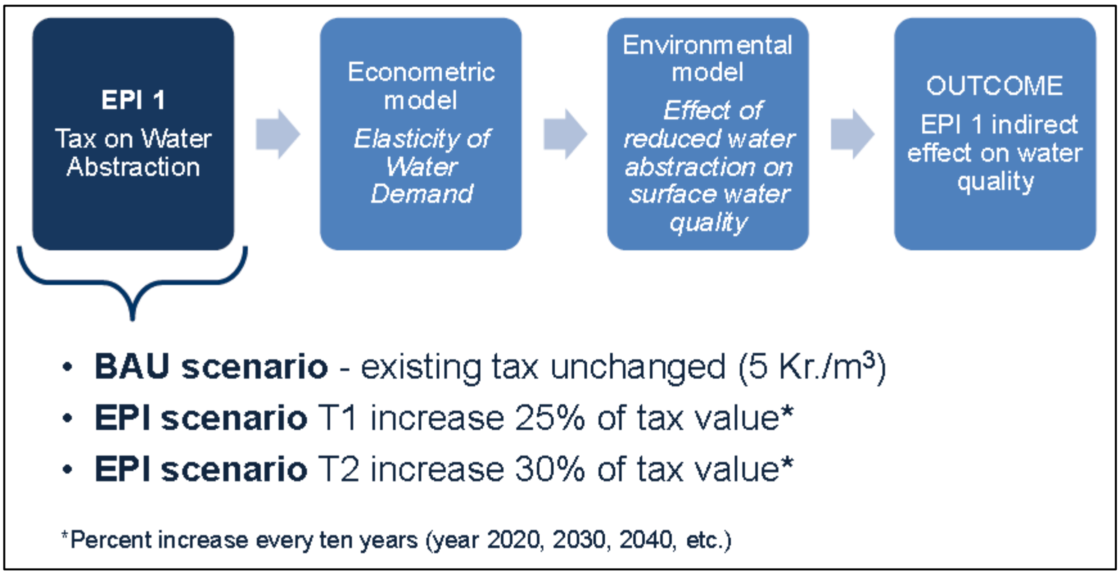


Figure 4.1: EPI1 scenarios.

4.2 Policy Design EPI2

The second EPI (EPI2) relates to the tax on nitrogen use. Farming and forestry purposes remain exempt under the €0.67/kgN (5 DKK) tax on fertilizer nitrogen introduced in Denmark in 1998. The objective here is to estimate benefits achievable by reducing the nitrogen load from diffuse sources with a nitrogen tax, in particular the related improvements of water quality but also other environmental pressures.

The hypothesis is that application of the nitrogen tax (EPI2) will lead farmers to improve utilization of nitrogen in animal manure and reduce the use of mineral fertilizers. Farmers would effectively reduce their N-load to agricultural land.

Reduced N loads from diffuse agricultural sources in the ORB should, in turn, lead to improvements in surface water quality (reduction of the concentration of nitrates) due to reduced N leaching from land to water bodies as well as to a reduction of other environmental burdens. Thus, EPI2 addresses a specific environmental contaminant (N) and a specific category of users (farmers), to explore how it might contribute to solving a specific problem (N load from agriculture).

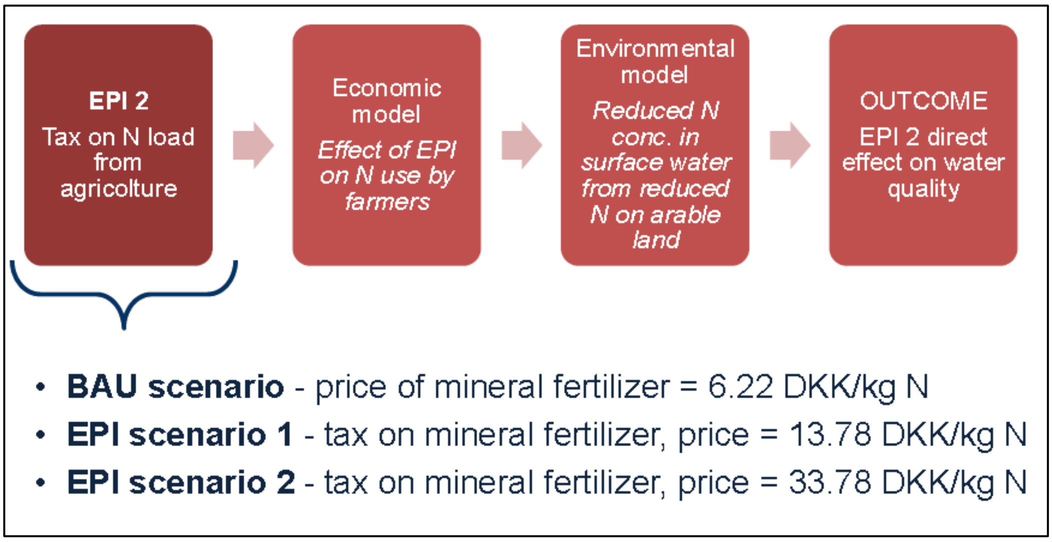


Figure 4.2: EPI2 scenarios.

5 Methodologies and tools

The overall methodology applied in our analysis follows from the EPI-WATER assessment framework, as developed under WP2 and WP3 (see figure 5.1). For the purpose of an assessment of the possible outcomes of applying the proposed EPI's, reference is made not only to the environmental criteria but also to the economic criteria and - to a certain extent - the distributional criteria. We are interested in what environmental improvements can be obtained, but also in what the potential costs will be and who in society that will be likely to have to shoulder these costs.

On the basis of this performance oriented analysis the second step in our assessment is more conceptually oriented, and focuses on four key dimensions of EPI-application. These include the institutional background for the EPI's in question as well as the issue of policy implementability, i.e. the involvement and position of various stakeholders as well as the conformity with EU legislation. Furthermore the conceptual analysis addresses the transaction costs, which include not only the direct administrative costs but also the wider adaptation challenge in relation to the regulatory framework, as well as the information uncertainty involved in our ex-ante assessment of the EPI's.

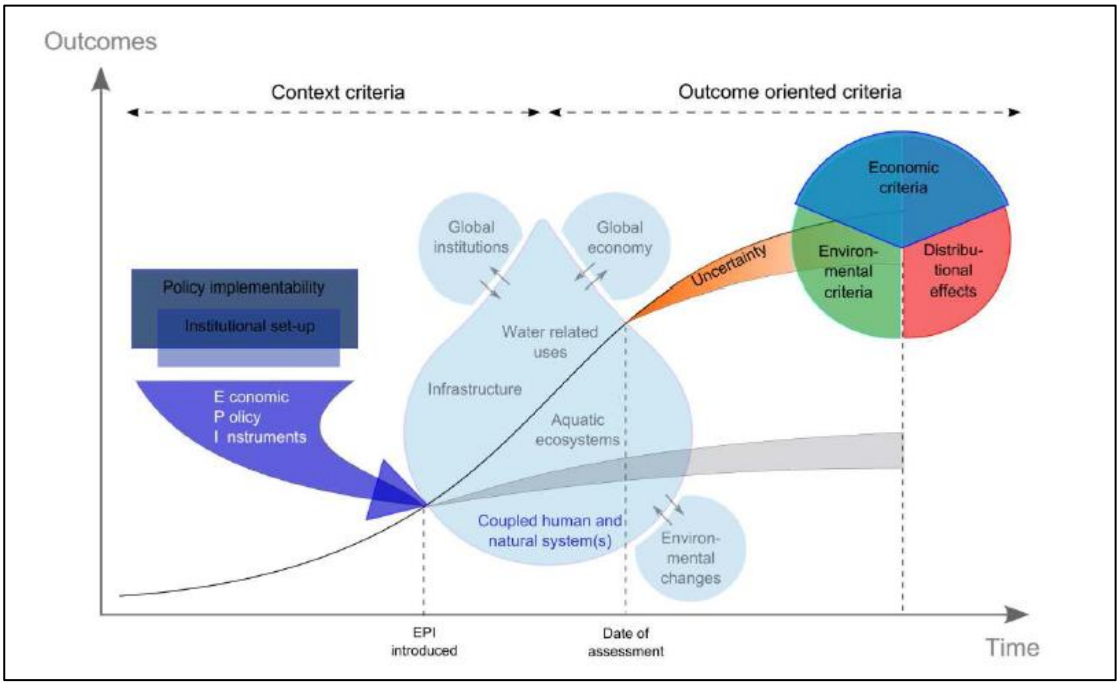


Figure 5.1 General assessment framework for EPI-Water's ex-ante studies.

5.1 Methodology EPI1

We have used regression analysis to determine the relationship between price of drinking water and water consumption, on the hypothesis that an increase in water price leads to a decrease in water consumption. The technique allows for the quantification of the price elasticity of water demand. By knowing the value of elasticity, the effect that a marginal increase in price has on the water demand can be calculated. The effect of EPI1 can then be estimated in terms of reduced per capita and absolute water abstraction and a measure of the reduced pressure of economy on the natural reservoirs in the basin is thus obtained. The analysis covers the sole household sector, as other water users were not considered for the reasons stated above.

Previous econometric studies (Arbués et al., 2003; Olmstead et al., 2007; Ruijs et al., 2008) show that water demand for households is not only influenced by the price of water, but also by several other variables: economic factors as e.g., income, size of the house, presence of water-using appliances; and climatic factors as e.g. temperature and precipitation. The studies from the available literature mainly use data referring to the single household level. We were not able to achieve such a level of detail: our primary data on water consumption and price are at municipal level for a time-span of 30 years, and have been provided by *Vandcentersyd* (VCS), the water supplier in Odense, which is the biggest city in ORB. Data are assumed to be representative for the entire ORB. The total water price in Odense is given by a fixed component, that is the same for each user, and a variable component changing according to the amount of water used by each user. The variable price is linear (no block prices). The variables examined in the study are reported in table 5.1.

Variable (V)	Details and unit	Source
ehWS	Estimated water sold to households [m3]	VCS[2]
POP	Users [person]	VCS
ehPC	Estimated per-capita household water cons. [m3/person]	=ehWS/POP
dVP	Deflated variable price [Kr./m3]	VCS
dFP	Deflated per capita fixed price [Kr.]	VCS
dINC	Deflated income [Kr./person]	DK-stat

Table 5.1: Variables (V) considered in the analysis

Data are given for years 1983-2010 and the economic variables are corrected for inflation. In the regression analysis method water consumption is the dependent variable (Y) and economic factors (such as the price of water, income, etc.) and climatic ones (temperature, precipitation, percentage of cloud cover) are independent variables (V_1 , V_2 , V_3, $\ldots V_k$). The linear regression model takes the form of:

$$Y = \beta_1 * V_1 + \beta_2 * V_2 + \beta_3 * V_3 + \ldots + \beta_k * V_k + \varepsilon$$

That for our case becomes:

$$ehPC = \beta_1 * dVP + \beta_2 * dFP + \beta_3 * dINC + \beta_4 * T + \ldots + \varepsilon$$

Where: $\beta_1, \beta_2 \ldots \beta_k$ are known as regression coefficients. The interpretation of β_k is the expected change in the dependent variable for a one-unit change in the related variable V_k (or equivalently, 1% change if variable V_k expressed in logarithms) when the other dependent variables are held fixed. Moreover, ε is the error term capturing all factors that influence the dependent variable, other than the explanatory variables. Several assumptions have to be verified such as independence of errors, homoscedasticity, lack of multi-collinearity among the dependent variables, exogeneity, linearity, and endogeneity. The linear regression model has been fitted using the Ordinary Least Squares (OLS) approach. We applied both linear and log-log regression models.

Once the elasticity of water demand is estimated, the value is used to predict the reduction in per-capita household water consumption, and the EPI1-related water savings compared to the BAU scenario. This information feeds the hydrological model NAM (*Nedbør Afstrømnings Model; Rainfall Runoff Model*). The lumped hydrological model NAM (DHI, 2008), was used to convert climate data into daily river runoff estimations. NAM feeds water into the river from three different sources, 1/ ground water, 2/ inter flow, 3/ surface water. The main reason for using NAM is to obtain this source split of the river discharge.

[2] Extrapolated from data provided by *Vandcentersyd* http://www.vandcenter.dk/

River water originates from different sources; in this case we consider groundwater and surface water (in NAM model terms it is interflow (through upper soil layers) + surface water). Groundwater has a much longer travel time from precipitation till entering the river than surface water. During this longer travel time a large part of the nitrogen that was originally in the water when leaving the upper soil (root zone) is removed (retention) – it is primarily turned into nitrogen gas through denitrification (both chemical and biologically). Therefore groundwater entering the river has a lower nitrogen concentration than surface water.

Groundwater abstraction is done from groundwater aquifers and thereby the flow from aquifers to the river is reduced by the abstracted amount. Therefore the share of river water originating from groundwater is reduced, while the share of surface water is increased. As surface water in general has a higher concentration of nitrogen than groundwater, the river nitrogen concentration will increase with increased groundwater abstraction. Thus, by curbing groundwater abstraction and thereby increasing the share of groundwater over surface water in the river, the N-concentration in the river will drop.

Later, the abstracted groundwater will in many cases be discharged again to the river at a different location, closer to where it has been consumed and the waste water is treated. In ORB most of the water is transported downstream to the city of Odense where waste water is discharged to the river. The amount of nitrogen in the abstracted groundwater will enter the river as a part of the nitrogen in the waste water.

Our analysis is based on the hypothesis that, due to the physical structure of the water balance of ORB, changes in water quality are expected to be more significant in the river segments upstream to the city of Odense rather than in the fjord. This may allow for improvement in river water quality, which will support biodiversity and improve the quality classification. Nevertheless, the same amount of water and nutrients will end up in the fjord, no matter the intensity of water abstraction in the upstream segment of ORB. The reduced abstraction will mainly allow improved water flows in the upper segments of the catchment, thus improving the water quality of smaller water courses for instance. Changes in water quality at point-monitoring stations in the ORB are taken as output for the study.

5.2 Methodology EPI2

The first objective in the ex-ante assessment of EPI2 is to determine how much farmers will reduce the use of N when this is taxed. The model used to determine the response of farmers to an increase in the price of fertilizers is an economic optimization model developed specifically for ORB.

Farmers have to maximize their profit based on a series of restrictions: farm type and dimension, crop distribution, price of the fertilizers, regulations (limits by law in the amount of fertilizers to be used), etc. The model is implemented in GAMS with MS Excel files as input spread sheets. Information about the model is available in (Fonnesbech-Wulff et. al., 2010). The model includes:

- A data matrix descriptive of all ORB farmers, reporting respectively ID code of the farm, dimension, type of activities, and crop distribution;
- Several yield functions (*Yield = f(amount of fertilizer)*);
- Information about the price of crops,
- Information about the costs that farmers have (prices of fertilizers and pesticides, and crop-specific fixed costs).

The model is calibrated on the ORB, with reference to conditions of year 2005. The output of interest from the model is the optimal amount of fertilizer that maximises the profit, and in particular the (economically) optimal amount of N applied to land by farmers, including also the N included in animal manure.

This information in the next step of our analysis feeds N-LES, a model for calculation of nitrogen losses at catchment scale (Simmelsgaard et al., 2000). The N-LES model for arable land N-LES was developed based on observations of annual leaching of nitrogen from the root zone from both experimental fields and fields in normal agricultural production in Denmark. The model effects are inputs of total-nitrogen added in the crop rotation seasonally, nitrogen fixation, soil type, water percolation through the root zone, and crop type. In the N-LES CAT concept a catchment is divided into a number of sub-catchments. N-LES runs for each sub-catchment on a number of representative combinations of land management, soils and climate. Root zone leakage from non-arable land is included, as well as retention during subsurface transportation (groundwater) and retention in surface waters. The model is calibrated on the ORB. Therefore, the output of interest is the concentration of nutrients in surface water at specific monitoring stations within ORB. The model is used to calculate the reduction in NO_3 conc. in the monitoring stations at specific water bodies resulting from a reduction in N load from agriculture.

6 Performance

6.1 Results EPI 1

Based on the hypothesis that consumers will respond to changes in total price, we included both variable price and fixed price in the model. Several simulations were performed by considering different groups of independent variables (variable price only; variable + fixed price), different demand functions (linear; log-linear), and by including/excluding specific independent variables (e.g. price + climate variables, price + income, etc.). The following models were found where *dfVP*, *dfFP* variables are significant, whereas *dfINC, T, C, S*, and *P* are not. Models have been controlled for endogeneity by solving them with an Instrumental Variable (IV) (in the first stage *dfVP* is quantified by using the variables *POP* and *dfFP*) and by performing the Hausman test. No endogeneity was found. Results of the Ordinary Least Squares (OLS) model are thus reported for two different regression models M1 and M2.

M1 - Solve by OLS:

$hPC = 71.160 - 0.464\ dfVP - 0.017\ dfFP$

$R^2 = 0{,}952$ Significance: constant: 0.000; *dfFP*: 0.006; *dfVP*: 0.000

M2 - Solve by OLS:

$\ln ehPC = 6.047 - 0.287 \ln dfFP - 0.118 \ln dfVP$

$R^2 = 0{,}928$ Significance: constant: 0.000; ln*dfFP*: 0.000; ln*dfVP*: 0.003

Once the formula for the demand function $Q_d=F(P_d)$ (where Q_d is quantity of water demanded and P_d is its price) is known, the price elasticity E_d of water demand (intended as the responsiveness of the quantity demanded of water to a change in its price) can be calculated as:

$$E_d=P/Q_d * (dQ_d/dP_d)$$

For the case of M1, the point-price elasticity (i.e. the elasticity calculated for each year according to the equation above) E_d is negative and its absolute value is increasing in time: E_d ranges from the value of E_{d_1995} = -0.07 (year 1983) to the value of E_{d_2010} = -0.48 (year 2010), whereas the average elasticity calculated for all 15 years is of E_{d_mean} = -0.36. Not surprisingly, water demand is relatively inelastic. Similar considerations are valid for M2: since the function is of log-log type, the price elasticity calculated with this model is the coefficient $E_d = \beta_1 = -0.11$.

The elasticity is used to determine changes in per capita consumption due to increases in price. This is especially important for the analysis of future scenarios.

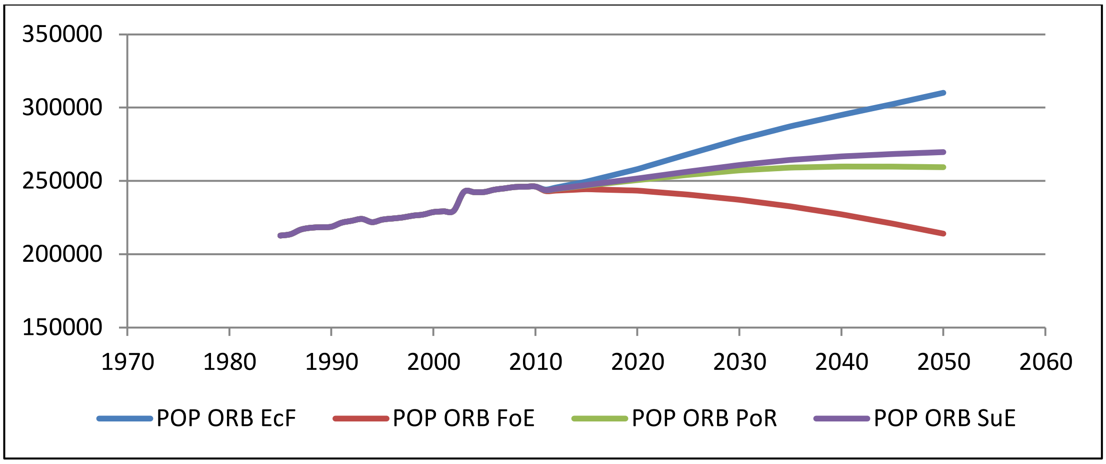


Figure 6.1 Projected population (POP) scenarios for ORB

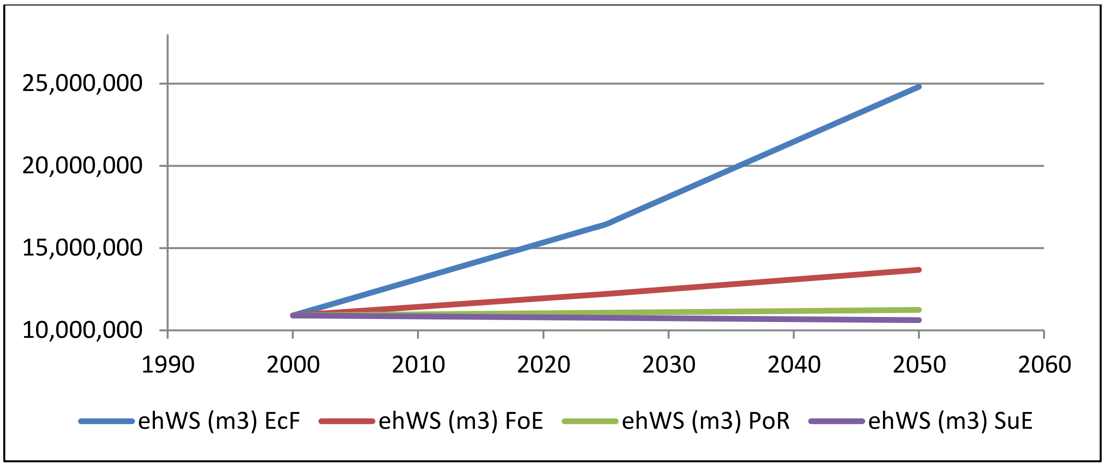


Figure 6.2 Projected water withdrawals (ehWS, in m3)

Figure 6.1 and 6.2 display future projections for population (POP) and water use (*WS*) in ORB based on the SCENES and SSP scenarios. Population projections of EcF (Economy First) scenario for 2020 are comparable to those of Statistics Denmark. The projected water withdrawals are driven by expected GDP-increases (annually about 2% in EcF), resulting in more household water appliances and comfort.

Table 6.1 reports results for the Economy First scenario. The two EPI1 water supply tax increases (T1 and T2) are applied (with the appropriate elasticities, M1 and M2) to explore what tax rate increases are required to curb water demand at a stable level. T1 and T2 will curb water demand - per household - with 1-2%.

Below we explore whether an increase of the water tax with 25% per decade will be sufficient to offset increases in water demand and maintain the water flow in rivers, keeping in mind the delicate water balance which exists at catchment level. The results indicate that the Water Supply Tax will need a doubling to a level of €1.32-1.48 per m3 to maintain abstraction at a stable level. This result does not take into account increases in precipitation driven by climate change however.

Table 6.1 provides data and results for the 'Economy first' scenario. The findings suggest that under these circumstances even a doubling of the Water Supply Tax will not be sufficient to curb demand to the level of water availability. Results for the three remaining SCENES scenarios are reported in Annex 1.

Scenario EcF		**2015**	**2020**	**2025**	**2030**
POP ORB		251,188	260,061	270,270	280,092
WS (m3)		24,378,707	26,277,887	28,177,068	31,041,628
Future Tax (€)	T1 (25% / 10 y)	0.85	1.05	1.05	1.32
	T2 (30% / 10 y)	0.87	1.14	1.14	1.48
Δ-ehPC (M1, elasticity= -0.366)	T1	-0.5	-1.0	-1.0	-1.7

	T2	-0.5	-1.3	-1.3	-2.2
Δ-ehPC (M2, elasticity= -0.287)	T1	-0.4	-0.8	-0.8	-1.4
	T2	-0.4	-1.0	-1.0	-1.7
Water savings (m3)	T1M1	114297	265961	276525	486114
	T2M1	137157	326246	339204	610495
	T1M2	89502	208264	216536	380657
	T2M2	107402	255470	265617	478055

Table 6.1: Water demand projection with Economy First Scenario plus taxation.

The first EPI scenario assumes that the water supply tax is introduced in 2015 at a level of €0.85/m^3 and an increase of 25% occurs every ten years (year 2020, 2030, 2040…). The increase in the water supply tax, from €0.85/ m3 to €1.32/ m^3 during the years 2015 to 2030, results in a substantial decrease in the estimated household per capita water consumption from 0.5% to 1.7% or from 0.5% to 1.4% depending on the model specification. Therefore, significant water savings can occur ranging from 114,000 m^3 to 486,114 m^3 or from 89,502 m^3 to 380,657 m^3 depending on the model specification. Slightly more water savings can occur with the second EPI scenario when the water supply tax increases by 30%. In this case, the estimated household per capita water consumption decreases up to 2.2% or 1.7% depending on the model specification, whereas water savings can reach up to the level of 610,495 m^3 or 478,055 m^3. In both cases, it can be observed that adjustment of the EPI can create substantial water savings in the future.

Implications for water quality

Historical data for water demand have been used as input to the water modeling in NAM in order to establish the spin-off effect for river water quality of the Water Supply Tax (EPI1). The reason for our approach is the poor quality of many water courses, which water planners have linked to reduced water flows (see above). We do so in order to separate out impacts of the Water Supply Tax on river quality in ORB. We focus on one important chemical parameter, the nitrogen concentration. As N-concentrations to some extent echo ammonium, reductions might be expected to support fish-life and habitat species. Our purposes are partly illustrative because water planners have so far disregarded the potential role of EPI's.

We explore two sub-catchments; the larger Odense river (with good data) and the smaller Holmehave river (partly based on simulations). The latter is currently subject to excess water abstraction and is representative of the 290 km of smaller water courses with insufficient water quality due to quantity issues.

The lumped hydrological model NAM (DHI, 2008), was used in converting climate data into daily river runoff estimations. NAM feeds water into the river from three different sources; 1) Ground water, 2) Interflow, 3) Surface water.

A simple model identifying groundwater and surface water nitrogen concentrations, respectively, was developed. The model is based on nitrogen concentration measurements (n = 1399) from the period 1996-2000 (Baseline). Periods which were modeled to have 100% base flow (Groundwater flow) in the river were identified for Kratholm at River Odense (DMUnr 450003). The mean nitrogen concentration of the 100% groundwater fed river water was calculated to 3.2 mg/l. Because there is a trend towards higher concentrations with higher base flow values a regression model was calculated (EQ. 1).

EQ. 1 $$N_{conc} = 3.2573Q_{ground\ water}^{0.109}$$

N_{conc} is the ground water (base flow) nitrogen concentration in mg/l. $Q_{groundwater}$ is the base flow discharge (groundwater) in m^3/s.

The Nitrogen concentration in surface water was calculated as a residual for all days with >0.5 m^3/s surface water discharge in the river. The mean surface water Nitrogen concentration was calculated to 11.1 mg/l. For Holmehave stream, the mean groundwater Nitrogen concentration is used instead of EQ. 1.

	N (mg/l) observations	N mg/l groundwater	N mg/l surface water	N mg/l River	r^2
observations	1399	3.2	11.1	5.3	-
Simulated	-	3.4	11.1	5.6	0.69

Table 6.2 Nitrogen model calibration statistics.

Measured groundwater abstractions with spatial distribution were done using data from JUPITER. The water abstraction data (from JUPITER; 1996-2000) refers to a groundwater aquifer in each sub-basin, and we maintain this spatial distribution in all scenarios.

NAM is run on daily records of three climate/weather parameters for the standard period 1989-2001 including both dry and wet years:

1. Observed daily precipitation (10 km grid from DMI) (Thodsen 2007)
2. Calculated daily potential evaporation (Thodsen 2007)
3. Observed daily Temperature (20 km grid from DMI)

NAM is calibrated against observed daily values of river discharge from the ODA online data base. NAM is calibrated, using the standard auto-calibration routine. A maximum of 100,000 model calibration runs were performed. The objective functions being the overall water balance and the root mean square error RMSE (Table 6.3).

	Area km^2	**Runoff (mm/y)**	**WBL%**	**R^2**
Odense R. Kratholm	487	290	0.7	0.95

Holmehave stream	36	262	1.4	0.87

Table 6.3 Catchment information and calibration statistics. Model WBL% water balance error in % for the calibration period.

Water abstraction in Holmehave sub-catchment is substantial >100mm/year, which makes it difficult to make a meaningful calibration. The, by far, most important abstraction point in this sub-basin is located close to the border to the neighboring sub-basin. Therefore it is very likely that a large part of the abstraction from this well field origins from the neighboring topographic sub-basin (meaning that some of the water fell as precipitation in the neighboring sub-basin and runs under ground into "this" sub-basin). Therefore the simulated groundwater abstraction values from this sub-basin is reduced by 30% assuming that 30% of the abstraction comes from the neighboring topographic sub-basin, cf. table 6.4.

Observed values of groundwater abstractions for the period 1998-2000 has been used as the baseline period, as the water tax was phased in gradually, with the full rate obtained from 1998. These abstractions have been used in the calibration of the NAM models.

Altogether seven scenarios have been run:

1. Before water taxation (average of abstractions 1983-1993)
2. WS1 taxation scenario; mean abstractions 1994-2010, M1
3. WS2 taxation scenario; mean abstractions 1994-2010, M2
4. EcF future scenario; mean abstractions 2040-2050
5. FoE future scenario; mean abstractions 2040-2050
6. PoR future scenario; mean abstractions 2040-2050
7. SuE future scenario; mean abstractions 2040-2050

Changes in groundwater abstraction following from the different scenarios have been modeled to be implemented proportionally (with the relative percent change) for each well. In reality new abstraction sites might come into use, but as the overall water balance is fragile in the catchment, this approach might also fall short of the water quality targets.

	units	Odense R. Kratholm	Holmehave stream	Holmehave stream 70%
Baseline	mm/month	1.58	11.0	7.7
Before taxation	mm/month	1.86	14.5	10.2
WS1	mm/month	1.46	11.3	7.9
WS2	mm/month	1.43	11.2	7.8
EcF	mm/month	2.82	21.9	15.3
FoE	mm/month	1.61	12.6	8.8
PoR	mm/month	1.33	10.4	7.3
SuE	mm/month	1.26	9.8	6.9

Table 6.4 Mean monthly ground water abstractions for baseline and scenarios in catchments.

The NAM model is run on a standard time period (1989-2001) to standardize the climate. The standard period is for all NAM runs, thus both the baseline runs and all scenario runs. The standard period is used to avoid climate signals (e.g. signals from wet and dry years) interfering with the water abstraction signals. The applied approach ensures that all modeled differences origins from differences in water abstractions.

Results on changes in ground water river discharge and river nitrogen concentrations are given for the baseline and all scenarios, cf. tables 6.5 and 6.6.

For Odense river the daily average water volume flows were 2% less in the pre-taxation decade (1983-93), while for Holmehave Stream flows were 12.6% less during this period.

	Description	Mean Q	Δ% Q	Mean BF m^3/s	Δ% BF	Mean N conc. mg/l	Δ% N conc.
Baseline	Mean 98-00	4.54	-	2.03	-	5.85	-
Scenario 1	Mean 83-93	4.45	-2.0	1.94	-4.5	5.88	0.5
Scenario 2	WS1	4.53	-0.3	2.02	-0.3	5.86	0.03
Scenario 3	WS2	4.53	-0.1	2.03	-0.1	5.85	0.01
Scenario 4	EcF	4.28	-5.8	1.77	-13.0	5.95	1.6
Scenario 5	FoE	4.49	-1.0	1.98	-2.3	5.87	0.2
Scenario 6	PoR	4.54	0.1	2.03	0.2	5.85	-0.02
Scenario 7	SuE	4.56	0.4	2.05	0.8	5.85	-0.1

Table 6.5 Results for Odense river at Kratholm (DMUnr 450003).

	Description	Mean Q	Δ% Q	Mean BF m^3/s	Δ% BF	Mean N conc. mg/l	Δ% N conc.
Baseline	Mean 98-00	0.263	-	0.095	-	5.70	-
Scenario 1	Mean 83-93	0.230	-12.6	0.062	-35	6.82	20
Scenario 2	WS1	0.260	-1.1	0.092	-3.1	5.75	0.8
Scenario 3	WS2	0.258	-2.0	0.090	-5.5	5.79	1.6
Scenario 4	EcF	0.177	-33	0.009	-91	10.42	83
Scenario 5	FoE	0.246	-6.4	0.078	-17	6.12	7.4
Scenario 6	PoR	0.264	0.2	0.096	0.6	5.69	-0.2
Scenario 7	SuE	0.268	2.0	0.100	5.5	5.63	-1.4

Table 6.6 Results for Holmehave stream (DMU ID nr 450080)

The Water Supply Tax has had some influence on water flows. Scenarios 2 and 3 explore this on basis of the two elasticities derived previously. For Odense River a flow increase of 0.1-0.3% must be attributed to the Water Supply Tax, while for Holmehave stream it is a flow increase of 1-2%.

For Holmehave stream the modeling suggests that N-concentrations were 20% higher in the pre-taxation decade. For the larger Odense river the differences for our water quality parameter is negligible. Again, the direct impact of the Water Supply Tax is only a fraction of the difference. For Holmehave Stream N-concentrations have been reduced with 0.8-1.6% attributable to the tax.

The Water Supply Tax represents only one component of the water price, which implies that the above identified impacts of water pricing must be considered to be higher when considering the full water pricing regime. Full-cost water pricing was introduced in legislation as a requirement from 1992 in Denmark. Compared with the pre-taxation decade (1983-1993) the deflated, real effective water price in ORB – including all components – has increased from €1.97/m^3 (14.7 DKK) to €5.61/m^3 (41.8 DKK), the Water Supply Tax at €0.67/ m^3 (5 DKK) being about 18% of this increase. In other words, we may consider the effects of full-cost water pricing to amount to about five times the figures recorded in the tables, suggesting that a 5-10% flow increase in Holmehave Stream has to do with water pricing. Conversely its N-concentrations have been reduced with 4-8% due to water pricing.

For Odense river 0.5-1.5% can be related to EPI1 with full-cost water pricing. Hereby EPI1 is reducing flows to sewage treatment plants with 1-2 million m^3 and the resulting potential relief on discharges amounts to 6-12 tN annually. With less water being abstracted, the river and Fjord receive higher quantities of clean groundwater runoff, rather than of sewage waters with nitrogen concentrations of up to 8 mgN/l, the legally binding maximum.

The projection scenarios are complex to interpret. This is because the projection scenarios describe population and GDP increases jointly with an increase of water taxation. Although the Economy-First scenario with an adjusted water tax results in less water demand per household, it nevertheless suggests potentially significant impacts on water flows for Holmehave Stream; water flows would be reduced with about 1/3. For Odense river as a whole there would be a reduction of ~6%.

Changes in the corresponding quality parameter are listed in the tables. For Odense river the water flow reduction would result in nitrogen concentrations increasing with 1-2%. For Holmehave stream there could be almost a doubling of N-concentrations.

These simulations are suggestive only, as to the implications, but they demonstrate how it is possible to link quality parameters directly to the quantity assessment. The disentangling of the Water Supply Tax impact furthermore illustrates how the water quality change can be linked to a sector in the economy (household consumption). The water accounting guidance document states that “it is difficult to attribute changes in stocks of quality to the direct causes” (p110) but the present analysis indicates how it might be feasible with appropriate models.

Table 6.7 shows water quality classes of SRU (standard river units) for ORB. To the extent that the activity-driven changes in quality parameters result in changed classifications, this will be captured in the water accounting system. For instance if increased water flows change quality parameters so a distance of SRU’s achieve improved classification.

Quality	High	Good	Moderate	Poor	Bad	Sum
Main rivers	9	18	11			38
Main tributaries	39	89	85	28		241
Small rivers	15	81	170	50	40	356

Table 6.7: ORB water quality in SRU's (kilometers), excl. not classified or piped water courses.

The economic value of change in SRU classification requires monetization for linkage to a macro-economic input-output model. The EPI2 case study explores how physical parameters for water quality can be assigned monetary values and finalizes considerations to this effect.

The large effects for Holmehave stream in our future scenarios should be seen as illustrative. In case of large increases in water demand, water abstracters would more likely open new abstraction wells. Thereby the changed impact would be shared between several sub-basins. The illustrative approach nevertheless may characterize well the possible impacts of water abstraction around smaller streams, many of which already have inadequate water quality. In this respect it is noteworthy that the Sustainability scenario (SuE) will in fact help increase water flows for Holmehave stream.

6.2 Results EPI 2

The results of the economic optimization model are reported in table 6.8. For the baseline scenario and EPI2 scenarios regarding the amount of N applied to agricultural land and the change in farmers' profit as a result of a tax on mineral fertilizer. SCP20 denotes a resulting mineral fertilizer price (incl. tax) of €2.68 per kg N (DKK 20), while SCP40 corresponds to a resulting price of €5.37 per kg N (40 DKK) including tax. With the current market price of €0.83 per kg N (DKK 6.22) this implies tax rates of €1.85 (T1) and €4.54 (T2) respectively (equivalent to DKK 13.78 and DKK 33.78).

Scenario	Fertilizer type	Fertilizer (tonnes N)	Δ-Fertilizer (tonnes N)	Δ-Profit gross (million €)	Revenue (million €)	Δ-Profit net (million €)
BAU_T	Mineral	12,205	0			
$SCP20_T$	Mineral	4,386	-7,818	-13.8	8.1	-5.6
$SCP40_T$	Mineral	127	-12,077	-17.7	0.7	-17.0
BAU_{ORB}	Mineral	8,835	0			
$SCP20_{ORB}$	Mineral	3,188	-5,646	-10.0	5.9	-4.1
$SCP40_{ORB}$	Mineral	92	-8,743	-12.8	0.5	-12.3

Table 6.8: Impacts of fertilizer taxation scenarios; modelling total and ORB-share.

There are about 2,000 farms represented in the model, many of which are possessing some land also outside the catchment district. To apply figures adequate for the actual Nitrogen flow within ORB, the model results have been specified for the share of land situated within ORB with appropriate scaling. The results indicate that the introduction of EPI2 can be expected to lead to a significant decrease in the use of mineral fertilizer.

The higher tax rate (T2) with SCP40 is in fact practically prohibitive to the use of mineral fertilizers. The more modest tax (T1) would reduce mineral fertilizer use with about 65%. For the two EPI2 scenarios the fertilizer nitrogen application in ORB will be reduced with 5,646 tN and 8,743 tN respectively. Only 11% of this reduction will be situated on land leaching directly to the sea rather than Odense Fjord. The estimated future Nitrogen flows to the Fjord are expected to decline from 1735 tN (2009) to 1075 tN (SCP20) respectively 700 tN (SCP40). A fertilizer tax will not impact the amount of livestock manure in the catchment area, but support improved utilization.

Farmers will experience a reduction of their profit due to the introduction of EPI2. With T2 the reduction in profits can be expected to be about 30% higher than with T1.

Revenues from the tax will drop with T2. This is reflected in revenues that would decline from €5.9 million with T1 to €0.5 million with T2. Hence, there are lesser revenues available for revenue recycling with T2. The change in net profits refers to the outcome with full revenue recycling to farmers (see table 6.8).

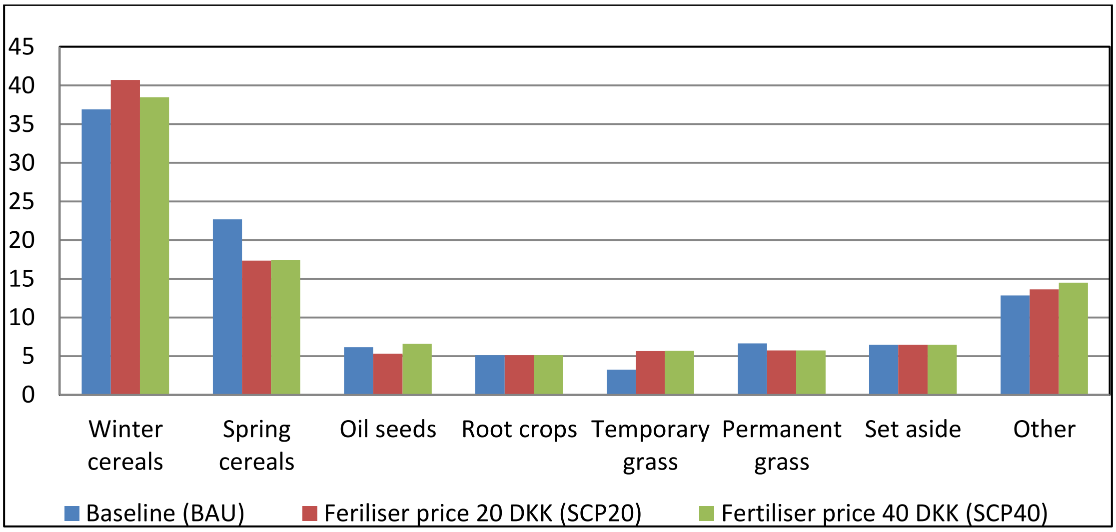


Figure 6.1: Relative crop distribution (% of total) for EPI2 scenarios, ORB

Farmers will choose to reduce significantly (or avoid) the use of mineral fertilizer, in order to curb payment of a fertilizer tax, or decide to shift to crops that require lower amounts of N. Figure 6.1 shows how crop distribution is affected by EPI2. An EPI impact on choice of crops is not evident from the analysis of crop distribution, although the introduction of a tax results in a change in the cultivation of cereals. The cultivation of winter cereals increases whereas that of spring cereals decreases. Minor changes can be seen for grass as well because this crop type requires less N fertilization. Nevertheless, the differences between T1 and T2 are not large regarding crop distribution. In the short term farmers are restricted by the specialization of their farm and the requirement for certain crops to support feedstock for their husbandry. T2 simply impedes farmers' use of N via mineral fertilizers and lowers output.

Some of the income reduction can be offset by revenue recycling. Indeed, by reducing the land value tax, the fertilizer taxation revenues can be recycled on a neutral basis per unit of farmland. This would reduce the profit loss to about €4.1 million for T1. However for T2 there would hardly be revenues to redistribute due to minimal mineral fertilizer use. For T1 the net loss of €4.1 million corresponds to €50/ha.

The modelling of changes in fertilizer-N is used in the following as input to the impact pathway analysis, which allows for an assessment of the attainable environmental benefits, among other things the improved sight-depth in the Odense Fjord. Map 6.1 shows the water body in focus with the ID's for the various monitoring stations. It has three entities; a) the shallow inner Fjord; b) the outer Fjord, north of the two islands; c) the Belt Sea.

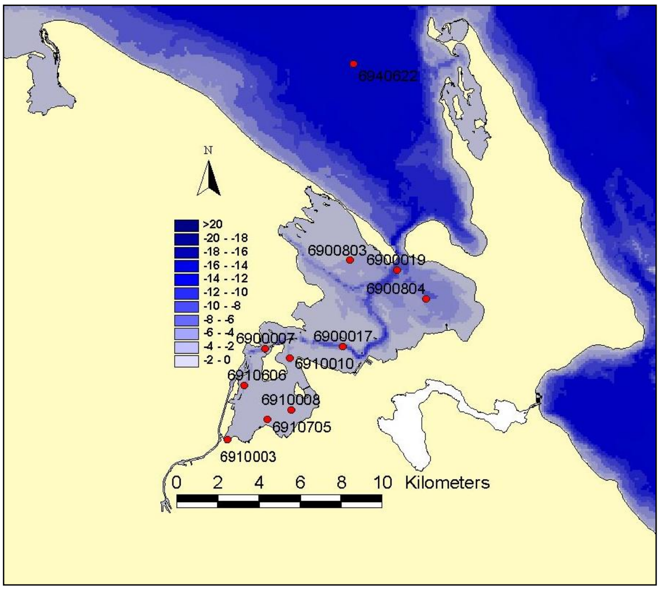
Impact pathway analysis

Impact-pathway analysis has been applied for ORB in the previous EU FP7 project EXIOPOL (Andersen et. al., 2011). This type of analysis links from arable land nitrogen application via N-LES modeling of leaching and nitrogen transport to the resulting chlorophyll values in Odense Fjord, from which annual average sight-depth is inferred (Hansen et. al., 2009). Sight-depth is a good indicator for ecological water quality, as one of the key ecological indicators – eel-grass – is known to be correlated with sight-depth (Carstensen, 2005; Jensen and Carstensen, 2012).

This type of analysis, presented in the following, allows for an assessment of the primary environmental impacts for water quality of introducing nitrogen taxation.

Table 6.9 provides the resulting estimates for the changes in sight-depth at four locations in Odense Fjord as a result of the two nitrogen taxation scenarios.

N-transport from field application of nitrogen fertilizers to Odense Fjord was subject to in-depth modeling with the N-LES model as well as with other calibrated models in the EUROHARP project. On basis of this modeling it was possible in the EXIOPOL project to derive resulting station-specific average nitrogen concentrations for the water body per unit of N applied to arable land. Table 6.9 provides resulting relationships for mineral fertilizers, and for comparison, for manure nitrogen.



Map 6.1: Odense Fjord with locations of monitoring stations for hydrochemistry data. River discharges from south of estuary.

	Unit	Fjord Site (ID of monitoring station) (with present range of sight-depth)				Total
		6900017 (2-4m)	6900804 (4-5 m)	6900019 (4-5 m)	6940622 (5,5-7,5 m)	
N-dispersion						
Mineral fertilizer *(M)*	Δ-(µg N/l) / (t $N_{applied}$/y)	0.0331	0.0107	0.0144	0.0026	
Manure *(O)*		0.0598	0.0193	0.0260	0.0048	
N-dose-response						
Sight-depth increment *(S)* SCP20	Δ- (cm Secchi) per (µg N/l)	0.485	0.957	0.896	1.317	
SCP40		0.679	1.109	1.060	1.380	
N-tax impact						
SCP20 (T1: €1.9)	Δ-(t$N_{applied}$/y)	-5,023	-5,023	-5,023	5,646	-5,646 tN
SCP40 (T2: €4.5)		-7,778	-7,778	-7,778	-8,743	-8,743 tN
Secchi depth	*Predicted (2009)*	*358*	*531*	*511*	*643*	
SCP20 (T1: €1.9)	Δ-(cm Secchi) *(M * S)*	81	51	56	19	
SCP40 (T2: €4.5)		143	84	93	30	
Unit values						
Site unit valuation cf. table 6.10 (HP)	€ / (cm Secchi) *(HP/100)*	€75.18	€337.53	€152.09	€6,838.28	
Monetary HP-benefits (per year)						
SCP20	Valuation sum	€6,067	€17,369	€8,587	€132,258	**€164,281**
SCP40		€10,720	€28,404	€14,155	€208,230	**€261,510**

Table 6.9. Predicted sight-depth changes with estimated house price impacts.

The site-specific dose-response functions for nitrogen concentrations and Secchi depth at monitoring stations have been estimated with regression analysis on basis of empirical monitoring data with long time-series for the Odense Fjord (see Carstensen in Hansen et. al., 2009).

High Secchi-depth responses are recorded for the outer Fjord, whereas for the Belt Sea coastal area where water is mixed with other nitrogen flows a more modest response is predicted. These differences reflect that nitrogen discharges from the catchment area will have decreasing impacts on water clarity as the distance to the river outlet increases.

When combining the N-dispersion values with the dose-response functions for each monitoring site it becomes possible to estimate the improvements in summer sight-depth that could be expected to result from reductions in nitrogen applications. Table 6.9 shows that for the EPI scenarios we should expect a 19-30 cm improvement in sight-depth in the Belt Sea coastal area (at station 6940622), whereas in the outer Fjord improvements in visibility would be 56-143 cm (at station 6900017 and station 6900019).

Monitoring station 6900017 is a good reference, as it is placed centrally in the waterway of the outer Fjord. For T1 an improvement in visibility of about 81 cm is predicted, while T2 would presumably yield nitrogen flow reductions allowing for an average sight-depth improvement of 143 cm.

Historical records give reason to believe that an eel-grass vegetation depth limit of 5.7 m is the reference condition for ecological state (MOE pilot, 2007:26; MOE, 2011) with the WFD objective of 'good' ecological water quality (EQR at 0.74) being to reach 4.2 m (MOE, 2011). Actual sight depth in the outer Fjord is about 3 to 3.3 m, with eel-grass vegetation currently at 2.6 m (Jensen & Carstensen, 2012; MOE, 2007; MOE, 2011:140). These depths refer to the Fjord waterway[3].

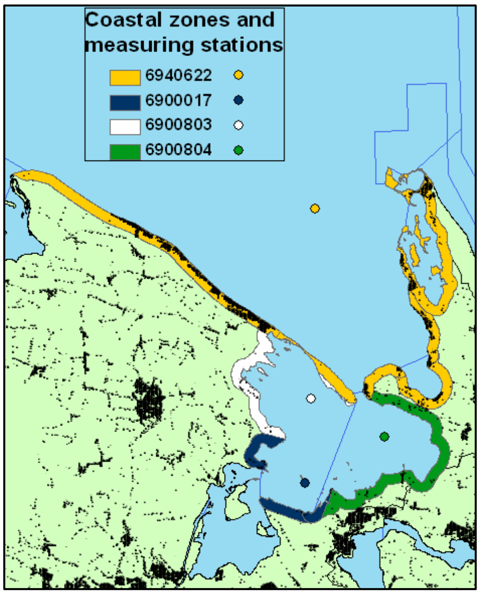
The EPI-induced improvements would be substantial and for both scenarios represent a marked improvement of current water clarity.

For the outer fjord SCP20 would bring sight-depth above 4.2 meters, so T1 enables attainment of the WFD objective 'good'. SCP40 (T2) would bring sight-depth to 5 meters or more, so that 2 of 3 stations would be likely to meet the quality criteria 'high'.

Because the EPI's target only mineral fertilizers there are virtually no implications for livestock manure disposal identified (N-losses from livestock manure are higher than from mineral fertilizer, cf. table 6.9).

[3] Odense Fjord is a shallow Fjord with several small islands. In the greater part depths are less than 2 meter, whereas 10% of the area has depths going below 4 m. Only the waterway has depths down to 10 meter. http://www.naturstyrelsen.dk/Udgivelser/Foldere/Reservater/Odense.htm

It is likely that N-taxation under both EPI scenarios would make it profitable for farmers to improve their utilization of manure-N, thus helping to reduce run-off – and change the leaching coefficients. However the N-optimization model does not feature possible shifts in technology curves and there is no dynamic efficiency from the EPI's implied in the analysis causing the modeled N-reductions to be lower-bound estimates.



Map 6.2: Coastal zones as linked to monitoring stations for the nitrogen leaching HP-valuation.

Monetary values of water quality

Above we have established that the costs to the farming community of improving water clarity with EPIs would amount to annually €4.1 to 12.3 million, depending on the specific scenario. These costs arise despite full revenue-recycling and as a result of reduced crop yields. WFD requirements aside, are the benefits sufficient to justify the action implied with EPI's? This is the question to which we now turn.

In the environmental economics literature an impact of water clarity on house prices has been demonstrated in several studies (Boyle et. al., 1999; Gibbs et. al., 2002; Ara, 2007). These house price (HP) impacts are small compared with the impact of houses being sited with a view over the water, but nevertheless amount to some percent change of the house price for a full meter change of summer sight depth. HP-impacts reflect that eutrophication events, or the risk of these, are having a tendency to revert prospective property owners. A recent study identified HP-impacts for a larger water body (one of the north-American great lakes, Lake Erie). With the study water body territory being comparable to the entire Danish Belt Sea - about 25,000 km^2 - we have found it justified to explore implications of water clarity improvement for house prices on basis of a benefit transfer function approach.[4]

Map 6.2 shows Odense Fjord with properties as located along the shoreline. The colored bands indicate which shore-strips are linked to sight-depth at the various monitoring stations in the analysis and the map also allows an inspection of the density of properties. Properties included in the valuation assessment exclude towns, as they are not on the shoreline. Table 6.10 provides valuation data for properties; in order not to factor in any temporary house price bubbles, the basic property values have been derived from construction costs and official land valuation.

A one meter of change in sight depth will accordingly produce an impact on house prices of, in average, 3.3% (see literature review in Andersen et. al., 2011). In our analysis property values are assumed to reflect the incremental change per unit of sight-depth change. This relation can be expected to be a one-off impact on house prices and needs to be annualized for the purposes of economic analysis. The benefit transfer function estimation essentially is a question of deriving the relative HP–response, while impacts are site-specific according to the density of the properties as related to Secchi-depth at monitoring stations.

Coastal zone	Properties, m2	Basic property value (million €)	Δ-Property value in € per meter Secchi	Annualised Δ-property value in € per m Secchi
6900017	2,343	3.1	103,485	7,518
6900804	10,519	14.0	464,599	33,753
6900019	4,740	6.3	209,355	15,209
6940622	213,115	283.2	9,412,783	683,828

Table 6.10. HP-impact in € per meter Secchi depth for ORB coastal area.

HP-benefits have been summarized in table 6.10, which links with site specific unit values presented in table 6.9. For the two EPI scenarios the benefits related to water clarity in the coastal area amount to annually €164,000 respectively €262,000 (see table 6.9). It can be noted that Secchi-depth implications are relatively modest for the Belt Sea shore strip, with implications for the aggregate valuation.

HP-impacts can be interpreted as an indicator for the willingness-to-pay for water clarity. Obviously the population at large would also have some interest in water clarity for recreational purposes, but we would not expect their preferences to be comparable to property owners that reside at the shoreline.

Söderqvist and Scharin (2000) surveyed bathing guests to the Baltic Sea about their willingness-to-pay for 'improving water clarity by one meter', so that *"in 10 years it will be possible to discern one's feet on the bottom wherever one bathes"*. It appears to be so far the only hypothetical willingness-to-pay (WTP) study linking valuation to a measure of Secchi depth. Söderqvist and Scharin report an

[4] There is anecdotal evidence indicating that improvements in water clarity have a separate and positive impact on property prices in Denmark.

annual willingness-to-pay of €47-€78 per person per meter[5]. In comparison for Odense catchment the 2,300 coastline property owners in our analysis are predicted to have a WTP per full meter Secchi depth of €740,000, which is about €320 each.

Table 6.11 provides estimates for the WTP of swimmers at Seden Strand near Odense city on basis of statistics indicating that 10% of a Danish city population go swimming from beach facilities within their city's proximity (Københavns Kommune, 2012).

	SCP20+ Belt Sea	SCP40+ Belt Sea	SCP20+ Seden	SCP40+ Seden
Bathing WTP/m	€47 per capita/m	€47 per capita/m	€47 per capita/m	€47 per capita/m
T1, T2 impact	0.19 Secchi-meter	0.30 Secchi-meter	0.81 Secchi-meter	1.43 Secchi-meter
Bathing WTP	€14.82 per capita	€23.40 per capita	€63.18 per capita	€111.54 per capita
Swimmers	18,700	18,700	18,700	18,700
Result: Mill-€/y	0.2	0.3	0.7	1.3

Table 6.11: Swimmers willingness-to-pay for sight-depth in Fjord (Seden beach) and Belt Sea.

Ancillary benefits

Observations in international literature suggest that "*Citizen concern about water is high when it comes to the taste of tap water, but low when the issue is the devastation of distant catchment areas or long-term conservation efforts to improve the basin quality*" (Fujita, 2005:115). On this background the potential co- benefits of water quality are briefly summarised.

In addition to eutrophication impacts there are three further impact pathways from arable land nitrogen application that deserve attention;

- Nitrate leaching to water aquifers supplying potable water
- Greenhouse gas emissions
- Ammonia emissions and deposition

Table 6.12 provides a more comprehensive assessment of benefits associated with reduced nitrogen application to arable land on basis of these three impact pathways.

Drinking water: Results from the EXIOPOL project regarding external costs related to N-leaching to water aquifers demonstrate the significance of potable water reserves for the monetary benefits, due to the potential health costs associated with drinking water nitrate. Mortality and morbidity costs related to these risks, as well as to other health end-points (cf. World Bank, 2007), add to the value of limiting nitrogen leaching. Epidemiological cohort analysis suggests that the risk rate for bladder cancers increase with nitrate contents in drinking water above 25 $mgNO_3/l$ (Weyer et. al., 2001).

[5] The AQUAMONEY results for ORB are a WTP of €43-64/capita for good ecological river status (Hasler et. al., 2009). Jørgensen et al. (2013) report a user WTP for improving water quality in Odense river of €63.

Water aquifers are regarded to be at risk mainly where there are insufficient protecting loamy soil layers. De-nitrification processes will be insufficient and allow some nitrogen to reach and accumulate in aquifers.

The dominating soil types in ORB are sandy loam (74%), coarse sand (21%), clay (1.5%) and peat (3.5%) (Hansen et. al., 2009:351). Although pressures are less severe than on the predominantly sandy soils in western Denmark, nitrate concentrations in drinking water have increased at several locations throughout the ORB catchment. Regional planning has officially classified 17% of the area as having nitrate sensitive groundwater. We take this figure to represent the share of potable water at high leaching risk. For the remaining catchment the nitrate pulse to aquifers is believed to be small. Modelling suggests that 99% of the nitrate will be removed with natural processes (Hansen et. al., 2009: 356).

On basis of the methodology of the health cost analysis in Andersen (2010) and Andersen et. al. (2011) we find monetary benefits of €2.4 million annually for protection of drinking water with reduced nitrogen application as a result of SCP20.

Nitrogen greenhouse gases: The natural nitrogen removal processes mentioned above result in release of nitrous gases from farmland, mainly N_2O. With an imputed GHG-cost of €20 per tonne CO2-equivalent, corresponding to mid-term expectations for the European ETS carbon allowance price, the SCP20 EPI scenario for mineral fertilizer reduction will generate a co-benefit of about €0.6 million annually.

Ammonia: Ammonia emissions mainly stem from livestock manure fertilizers, but there is also a smaller contribution from mineral fertilizers. The reduction in use of mineral fertilizers would yield less ammonia emissions. With an official ammonia emissions rate of 1.5% per unit of nitrogen applied our SCP20 scenario suggests reduced NH_3 emissions of 84 tonnes annually.

We value these emissions with the unit cost for NH_3 to Denmark according to the European Commission's CBA for the Clean Air For Europe strategy (AEA Technology, 2005). For consistency with our other monetary values the NH_3 unit cost has been indexed with the VOLY (Value of a life year) specific to Denmark (by applying standard purchasing-power parities to adjust average EU-values to Danish values).

	SCP20 **Ton N (not) applied**	**SCP 40** **Ton N (not) applied**	**External costs** **€ per kg N-fertilizer**	**SCP20 Benefits** **Million € /year**	**SCP40 Benefits** **Million € /year**
Drinking water -Loamy soils -Sandy soils	 4687 960	 7257 1486	 0.16 1.64	 0.8 1.6	 1.2 2.4
Greenhouse gas N_2O	5646	8743	0.11	0.6	1.0
Ammonia	5646	8743	0.22	1.2	1.9
Eutrophication -HP impact -Swimmers' WTP	 5646 	 8743 	 >0.02 0.02-0.25	 >0.2 0.4	 >0.3 0.8

Sum			2.18-2.41	4.8	7.6

Table 6.12: Monetary benefits achieved with reduction scenarios according to external unit costs of N-fertilizer.

The benefits of curbing ammonia emissions from mineral fertilizers on this basis amount to €1.2 million annually in SCP20. These are health-related costs, due to the atmospheric chemistry where NH_3 interacts with secondary sulphate and nitrate to form secondary particles that are part of the mass of $PM_{2.5}$. Secondary particles are transported hundreds of kilometres, where they contribute to human exposure regionally. OECD-guidelines (2006) recommend factoring in pollutants subject to international agreements when accounting for benefits.[6] There are further impacts from final deposition of ammonium that we have not been able to factor in here.

Assessment

With the co-benefits of reduced nitrogen application the analysis suggests that SCP20 offers aggregated benefits of about €4.8 million annually. For SCP20 it compares with costs of €4.1 million to farmers, suggesting that T1 is a viable option.

For the more ambitious SCP40 scenario that would allow water managers to re-establish the reference conditions for high ecological water quality see table 6.12 for a breakdown of the monetary benefits and co-benefits. SCP40 imposes costs to farmers at €12.3 million annually, while benefits of about €7.6 million. Despite several uncertainties, the benefit to cost ratio appears unfavourable to SCP40's T2 EPI.

In undertaking an assessment of the outcomes of the above analysis the following aspects need to be considered;

- Some environmental benefits have not been included or reflected in the monetary appraisal. These include notably biological resources such as fish and birdlife which also depend on Secchi-depth, but for which we are missing estimates for their response to water clarity as well as for their economic valuation. We suspect, however, that they might not add decisively to economic valuation. More importantly a regional aspect of Secchi-depth impacts could not be included, so the contribution of ORB nitrogen flows to water clarity at the regional scale of the Danish Belt Sea has been omitted. It might be a more serious omission.
- The N-optimization model provides a figure for the economic loss to farmers. This is essentially a budget-economic figure for their costs and not a welfare economic assessment. Farming is subsidised and some of the farming activity would not be

[6] There are potentially considerable benefits from ammonia reductions. Had our EPI resulted in reduced application of livestock manure the benefits from the associated a reduction per ton of N would amount to €3,400. In contrast reducing a ton of mineral fertilizer is valued at €216 for the avoided ammonia.

profitable without subsidies. Our analysis did not address how to obtain the maximum benefits from tax-payers' subsidies.

- Raising subsidies with taxes create economic distortions that would need to be factored in. The standard approach to considering distortions suggests 20%. Including this dimension in a welfare economic assessment for ORB might affect the overall balance of costs and benefits.
- The EPI's have targeted only mineral fertilizer. An N-input tax on all sources of farmland nitrogen has been proposed (Hansen, 1999) and would affect also livestock manure nitrogen. The economic appraisal suggests that any measure reducing on livestock manure would offer potentials for increased economic benefits. Not only is N-leaching higher per unit of manure-N, also ammonia emissions feature high external costs. Reductions in livestock breeding can generally be expected to result in more notable economic losses than changes in fertilizer practice. Still, an N-input tax might lead to utilisation rates for manure-N that are higher than currently the norm, which might offer prospects for 'win-win solutions' to the environment and the farm sector economy.
- With most of the monetized benefits related to other impacts than Secchi-depth improvements, it might be more appropriate to understand surface water quality improvements as a co-benefit to a more general N-exposure reduction programme.

Accounting for water quality with SEEAW

The recently published guidelines on water accounting state that;

> "7.30. Quality accounting is useful for following the evolution of the water quality and it furnishes an indication of the efficiency of the measures taken to protect or improve the state of bodies of water" (UNSD, 2012).

The evolution of water quality is being accounted for as part of the reporting obligations under various EU Directives, but the Water Accounts aim to bring together reports that are often disconnected. The ambition is to provide a tool that allows for an assessment of the efficiency of the measures taken to protect and improve water quality. When the water accounts are linked to economic sectors it should become feasible to assess more systematically the contribution, or trade-off, to economic welfare expressed with the value added. Provided that a water body, such as Odense Fjord, only has a defined absorption capacity for pollutants, the water accounts should enable an analysis of which sectors would provide the maximum economic value for a defined annual flow of pollutants.

Our case studies have addressed in particular non-point sources of pollution being significant for water quality; the water accounting guidelines make the following observations with regard to non-point sources;

> “4.7. Non-point sources of emissions cannot be measured directly but need to be estimated through models which take into consideration several factors, including soil structure and climatic conditions, as well as the delay involved in the pollutants reaching the water table. It is also difficult to allocate non-point emission sources to the economic unit that generates the pollutant because of the nature of those sources” (UNSD, 2012).

The case studies have implied the use of models for reaching the objectives set. There are no universal models available covering all aspects relevant for water accounting, different models need to be combined, some of which are site-specific. For different parts of the hydrological cycle various modelling complexes are available, with different levels of complexity. The choice of model hence may partly influence the results. Other EU research projects have explored the properties of different hydrological models and have carried out blind tests. Uncertainties in the estimates are endemic, in particular for exploring scenarios and marginal contributions of policy instruments aiming to influence behaviour.

Still, as demonstrated with our case studies it is in fact today not a major difficulty to assign non-point sources to their respective sectors. Being a precondition for linking water quality influences to economic sectors some effort is needed to identify the most appropriate modelling tools and to agree on a harmonised approach for their application for the purpose of water accounting at a European level.

There appears to be a certain ambiguity in the SEEAW as regards emission accounts and accounts for the quality of water bodies. The above paragraph is preceding one that in fact addresses the non-point source emissions (cited from SEEAW, our emphasis);

> “4.8. Emission accounts include all point source emissions of pollutants in wastewater and those non-point sources for which physical flows are recorded in chapter III, namely, urban run-off and irrigation water. Urban run-off is described in the emission accounts in terms of the pollutants deposited in urban areas and in the air, often as a result of transport or other economic activities. *Returns from irrigation water and rain-fed agriculture are described in terms of the pollutants which are added to the return flows from agricultural land, that is, fertilizers and pesticides that spread on the soil during infiltration into groundwater or run-off to surface water*” (UNSD, 2012).

The guidelines seem to imply that whereas it is possible to account for the origins of the flows (emissions) from non-point sources, one cannot allocate the resulting changes in the stock (water quality) to the relevant economic sectors. However, because observed changes in water quality can be explained with and linked to changes in pressures, this should not be a major obstacle, only a question about resources to mobilise the appropriate modelling tools.

We think the challenge is different, namely the site-specific character of the impacts, which cannot easily be captured within a macro-economic modelling framework at the national level. The influence of certain emissions (flows) on water quality depends entirely on the properties of the water body (stock) in question and to some extent also on the physical conditions for transport and dispersion into the environment.

The implication is that the monetary values which will need to be applied cannot be assigned pro rata to an IO-analysis for the individual emissions, as they are to some extent site-specific. More effort is required to explore these variations in greater detail. It might be that they can be clustered in categories and that the categories defined already in WFD for different types of water bodies can be useful for that purpose. The site specificity of environmental impacts applies for most pollutants and in the field of air pollution it has become customary to distinguish between a few key categories, such as urban and interurban areas. There is a higher degree of complexity in the aquatic environment, demanding careful analysis of the relevant categories. Linking to input-output tables for the purposes of macro-economic analysis will be complicated and remains a challenge yet to be sorted out (e.g. in WP5 of EPI-WATER).

While emissions per se can be assigned monetary unit damage costs, as it has been explored in several EU research projects, there is a need to develop methods also for assigning monetary values to the stocks of water. Conventionally this would require accounting for the use as well as the non-use values of water bodies. Use values of water bodies principally must comprise three aspects relevant to the economy; 1) life-support functions 2) resource input and 3) absorption capacity (sink). The non-use aspects mainly relate to amenity values. In addition there is an option value for each of these aspects.

As for the use values there is a dynamic relation between the various functions; if the absorption capacity is utilised to its maximum, it is likely to influence the life-support function for biological and human purposes. Obviously also the consumption of natural resources will reduce its availability for absorption or life-support. Some of these tradeoffs can be analysed with the concept of 'Ecological Utilisation Space' as it has been developed by Opschoor and colleagues in the early 1990's, which might be a useful stepping stone in drawing up water accounts with regard to water quality as a precursor to assigning monetary values (Opschoor and Weterings, 1994).

We can think of Odense Fjord as a water body for which water quality deteriorated as a result of successive steps over the last century. Some parts of the Fjord were converted to arable land through draining early in the 20th century. Draining of other lowland areas increased the leaching of nutrients to the Fjord, tapping on its capacity to sustain biological life. From the 1950's the use of mineral fertilizers increased rapidly, while the conventional disposal of animal manure for plant growth became a secondary waste product. With the 1960's came large flows of waste water sewage and discharge of cooling water from a regional power plant along with a number of industrial effluents. The growth in intensive animal husbandry from the 1970's multiplied nutrient leaching to the Fjord, with the implication that the fragile aquatic ecosystems reached a threshold. With the dying-off of eelgrass from the mid-1990's the capacity of the Fjord ecosystem to sustain not only the waste residuals but also the biological life as such greatly diminished.

With the concept of ecological utilisation space the diminishing space for the regenerative function can be described as a function of these different influences, each contributing only in part. With diminishing regenerative capacity we would see a declining economic value of the Fjord ecosystem, as it serves less and less the four basic functions identified above. This can be captured by valuing the Fjord at its current assimilative capacity.

7. Making it happen

This section addresses four questions from the assessment framework that concern the possibilities and potential obstacles to successful introduction of the EPI. These include the institutional context, which may be more or less conducive to adoption and functioning of the particular EPIs analyzed in this report; the transaction costs involved in implementing the EPI; policy implementability particularly as viewed by stakeholders and an assessment of key uncertainties.

7.1 EPI1: Water Supply Tax

The modeled EPI constitutes an improved version of the existing water supply tax. Hence, the governance framework as well as normative support for the proposed EPI is fully compatible with the proposed tax, and the principle of full-cost water service pricing has also been implemented. Thus, the current water supply tax was implemented to manage water demand and to protect groundwater via reduced water consumption (ECOTEC, 2001). The tax applies to water supplied to households and public buildings, but not to the agricultural and industrial sector. The tax is liable for abstracted water at water works, public as well as private, which then pass the tax on to their customers.

No changes in the normative or governance framework would therefore be necessary under this EPI.

As the EPI consists merely of an increase in the existing tax rate, it is assessed that it could be implemented without new transaction costs related to administrative expenses.

Water taxation has not traditionally been a politically charged issue, as it represents a payment for services. Moreover, as the industrial and agricultural sectors are exempted, a tax increase would not mobilise these strong interest organisations. However, taxation has become a more politically salient issue in Denmark following the tax stop policy of the government coalition of the 2000s, and also the current government has generally been hesitant to put forward new green taxes. On the other hand, as the Economy First shows that a tax increase would be necessary and sufficient to ensure a continued balance in water abstraction, an increase in the water abstraction tax increase may be politically feasible.

7.2 EPI2: Tax on mineral fertilizer-N

This section sketches the institutional context that might condition the successful implementation of a tax on mineral fertilizer. It includes formal institutions such as the existing legislative framework regulating water, the administrative setup for water management and the policymaking structure as well as informal institutions such as norms regarding water policy as well as inclusion of stakeholders. Changes to the normative and governance framework that would be necessary for introduction and proper functioning of the EPI will be discussed in the section below on implementability.

The EU water framework directive (2000/60/EC) and its associated directives constitute the main regulatory structure for water regulation and diffuse pollution from nitrogen has been identified as one of the main obstacles to Denmark's compliance with framework directive's mandate of achieving 'good ecological status'. Thus, the first round of river basin management plans targets nitrate pollution.

Denmark introduced significant legislation to curb water pollution from pesticides and nitrates during the 1980s and followed up with more regulation in the 1990s. Pesticide regulation included regulation regarding application, mandatory courses on application and the world's highest tax on pesticides. Nutrient regulation concerned primarily livestock density, application and storage of manure and for phosphorous rules regarding P in feed. Phophorus pollution was otherwise handled primarily through construction of waste water facilities.

The Water Framework Directive is transposed into 17 different legislative acts, the overarching legislative act being Executive Order regarding Act on Environmental Objectives for water bodies and nature protection areas (LBK. no. 932 of 24 September 2009). The act also links implementation of River Basin Management Plans with the Natura 2000 plans under the Habitats Directive (92/43/EEC) and the Bird Directive (2006/105/EC).

Current nutrient regulation includes several regulations of livestock holdings, including number of livestock per hectare, a cap on manure application, and rules related to storage of fertilizer. The cornerstone of nutrient regulation is a fertilizer quota which sets a cap on the amount of fertilizer each farmer can apply on his cultivated land; the quota is based on a standard for fertilizer needs differentiated by crops, soil type and climatic factors. The quota is non-tradable and therefore may be characterized as command-and-control regulation, although the fertilizer norms are based on economically optimal levels and farmers are allowed to allocate their quota among their fields as they please. In addition to the quote, large livestock farms are required to have an environmental permit further specifying measures to protect the environment, especially water, from nutrient runoff and leaching. Nutrient regulation also includes mandatory catch crops and winter cover.

Under the Rural District Progamme a number of voluntary programs have been set up to manage nutrients locally through subsidies for restoration of wetlands, buffer zones and similar area based measures. Recently, regulations were introduced requiring 10-meter wide buffer zones around lakes greater than 100 m^2 and along water courses (Danish AgriFish Agency, 2012).

While economic policy instruments so far have not been a prominent instrument in the regulation of nutrients (see also Rougoor et. al., 2001), EPI's are not unfamiliar to the agricultural sector as the tax instrument has been a significant element in the policy instrument portfolio regulating pesticide usage. Implemented in the mid-1990s as a simple tax on the sales price, the pesticide tax has been redesigned in 2012 to ensure that the tax more accurately reflects environmental and health effects of active ingredients; the tax rates were also generally increased to improve farmer response to the taxes (see below). The tax will take effect in 2013 following recent approval by the EU.

Administrative setup for water management: The Act on Environmental Objectives designates the Minister of the Environment as the competent authority for the 4 river basin districts in Denmark (§2, lit. 3). However, as of 2011 this authority has been delegated to the Nature Agency under the ministry. At the local level, the administrative structure includes all municipalities located within a sub-basin. Thus, a municipality may be involved in the administration of several sub-basins.

River basin management plans are drawn up at the level of the main sub-basin; these plans will thus be aggregated to make up the River Basin Management Plan (RBMP) for the district. River basin management planning has been affected both by a major reform of the government structure in Denmark in 2007 as well as repeated changes in the administrative structure and division of responsibilities within the Ministry of the Environment. Currently, the Nature Agency is responsible for development of the RBMPs while municipalities are charged with the actual implementation of the sub-basin plan and the programme of measures listed therein, as these concern the land within the geographical jurisdiction of the municipality and adjacent coastal waters. This includes wetlands, water courses, groundwater and waste water. In order to do this, the municipalities are required to draw up an action plan outlining how the sub-basin plan and the programme of measures will be implemented, although as the sub-basin plans are rather specific, it is not entirely clear how substantial the action plans will be (Nielsen et al. 2010). In addition to the administrative changes, river basin planning has also been surrounded by political conflict, and they have not yet been adopted. Recently, the plans as adopted were annulled by the Environmental Board of Appeal (2012), an independent administrative appeal board, which ruled that public hearing on the plans had been carried out with too short a deadline.

The Nature Agency through its local offices is responsible for collecting data and monitoring the status of the aquatic environment.

In addition to the river basin management administrative structure, municipalities and quasi-autonomous (municipal) water companies carry primary responsibilities for water supply and wastewater treatment.

Institutional arrangements for adopting and administering a nitrate tax: As the river basin authority and River Basin Management Plan adoption is placed with national authorities there is no decision-making structure specifically designated and limited to the Odense River catchment. As such a nitrate tax would have to be implemented either at the national level or jointly in the 8 municipalities located in the catchment. While municipalities do have the power to levy taxes, this latter option is not feasible for several reasons, including the fact that the commercial market for mineral fertilizers is not local. Furthermore, traditionally, agricultural regulation has been implemented at the national level in the form of general measures applying equally.
Likewise, the development of the RBMPs to this point has been carried out in a highly centralized manner and with measures applying uniformly across the country (Nielsen et al. 2013).

In the environmental policy arena there have been discussions and analyses about ways to differentiate policy measures spatially, according to sensitivity to pollution, nitrate and pesticide in particular. But since these would entail distributional effects they are typically discussed within a framework of compensation to farmers, not one of taxing farmers in some areas. Thus, a tax implemented in just one river basin would challenge an entrenched regulatory tradition.

Thus, it appears most likely that the proposed nitrate tax would have to be adopted by the Danish Parliament and would be implemented uniformly across the country.

Current and comparable taxes on pesticides and phosphorous are administered by the Ministry of Taxation and collected by tax authorities. Thus, the infrastructure to enforce the proposed tax is largely in place.

Stakeholder participation in the water policy arena: The nexus of environmental and agricultural regulation is an intensely politicized policy area in Denmark and characterized by active interest groups. The Danish Agriculture and Food Council constitutes a well-organized stakeholder which actively seeks influence on policy in this area. They have consistently and with some success resisted environmental taxes in agriculture (see below; Daugbjerg and Pedersen, 2004). A number of nature and environmental groups are also quite active, working for stronger measures to curb agricultural emissions. The Danish Society for Nature Conservation is the largest among these and has been active in policy discussions regarding water pollution and the role of diffuse pollution from agriculture. They tend to favor environmental taxes on agriculture. Other organizations representing the environment or nature are World Wildlife Fund and the Danish Anglers Association who are also active in this area.

DANVA, the association representing water and wastewater companies, takes an active interest in regulation of diffuse pollution, as agricultural leaching impacts directly on their ability to continue to supply untreated drinking water.

All of these groups are organized both at the national and the local level, although local groups are not organized along water catchment lines.

As stated in the introduction, the changes to the normative and governance framework necessary will be discussed in the section below on implementability.

Transaction costs

Transaction costs have not been estimated specifically for the EPI scenarios modelled in this analysis. However, a 2003 study commissioned by the Ministry of Taxation carried out a detailed analysis of a tax on mineral fertilizer and also roughly estimated implementation and other administrative costs establishing such a tax (MOT, 2003). Calculations done in preparation for the change in the pesticide tax offer further, and more recent, estimates of the magnitude of transaction costs.

The 2003 report argued that a tax on mineral fertilizer would be similar to the existing tax on mineral fertilizer from which most agricultural producers are exempt. But since a taxation infrastructure is already in place, the report suggests that a fertilizer tax levied on mineral fertilizers would entail very limited extra administrative costs at the governmental level (MOT 2003: 112). Thus, the tax agencies estimated the administrative costs related to a tax on mineral fertilizer to amount to about €0.15 million for implementation and a mere €15,500 in running expenses in addition to 1 man years for implementation and 4 man years for ongoing administration, including monitoring. However, the agencies did warn that this estimate assumed that the introduction of the task would not prompt illegal importing, in which case monitoring expenses would increase (MOT 2003: 183).

These numbers are comparable to estimates of the transaction costs related to the pesticide tax. The pesticide tax, until its recent redesign, was based on sales prices, which was expected to minimize inspection costs and administrative costs due the relatively small number of producers and importers (Minister of Taxation, 1995).

For the pesticide tax, it was estimated that non-recurrent expenses of setting up a price labelling system would amount to €0.4 million (2011 prices), while running expenses were estimated at an amount of €0.2 million (2011 prices). The running expenses were paid by the registered companies through payment for the price labels. This system is considered one of the ten most burdensome regulations for the companies within the jurisdiction of the Ministry of Taxation (see Pedersen, Nielsen and Andersen 2011). However, running expenses might be underestimated. In 2006, one of the two largest chemicals and feed companies estimated its labelling costs to be between €0.2 and €0.3 million per year (0.3 % of the company's turnover on pesticides (Landbrugsavisen, 2006, quoted in Pedersen, Nielsen and Andersen, 2011).

The case of the pesticide tax may also offer relevant information on monitoring of illegal imports. A task force has been set up to tackle illegal imports. From 2009 to 2011, the Environmental Protection Agency spent 0.5 man years per year on the task force, while the tax authorities have used between 0.75 and 1.25 man years per year on the task force and price label administration (email, tax authorities, December 2011; e-mail Environmental Protection Agency, December 2011, see Pedersen, Nielsen and Andersen, 2011). No figure was available for the monitoring expenses incurred by the Ministry of Food.

For producers and importers of mineral fertilizers, the 2003 report noted that they already administer the existing tax and thus would not incur new expenses. In fact, their expenses might be reduced as they would no longer have to administer a dual system – one for those who must pay the tax and one for those who are exempt.

The report also surmised that a tax might involve fewer transaction costs for farmers compared to the current quota system, provided that the tax would be administered by producers and importers and simply passed on to the farmer through fertilizer prices. This, however also assumes that the tax replaces the quota system entirely. The current quota system imposes considerable transaction costs on farmers, not least since fertilizer regulation has been linked to the cross-compliance mechanism of the Common Agricultural Policy. Therefore farmers pay their advisors to do the fertilizer accounting to ensure that there are no errors that might reduce their subsidies. A fertilizer tax, therefore, would not impose significant new transaction costs on farmers.

Implementability

This section provides an assessment of the implementability of the tax based on the institutional analysis above. Implementability is discussed in terms of opportunities and obstacles in the existing institutional framework, including the expected attitudes of stakeholders and their role in the policy process. Stakeholders have not commented directly on their attitudes and perceptions of the proposed tax, as they have not yet been able to participate in the study due to time constraints on the part of the key stakeholders. As a conclusion to the analysis of implementation barriers in the institutional framework, the assessment will discuss which, if any, of the changes to the normative and governance framework are necessary.

The assessment is divided into two subsections: one analyzing the compatibility of a tax regime with the existing policy or regulatory framework and one analyzing the policy-making processes, including stakeholder views and influence.

The analysis focuses on the SCP20 tax rate scenario, which indicated that T1 would reduce the nitrogen load to Odense Fjord by 660 tons N and meet the quality classification for the Fjord 'good' as stipulated in the River Basin Management Plan. This scenario also includes the possibility of recycling the tax revenue to farmers through for instance lower property taxes.

As the current water policy framework for environmental regulation of agriculture emanates from the EU and the national policy level, and as there is no evidence to suggest that local views differ significantly from national views on fertilizer policy, the discussion will be not be framed specifically at the Odense Fjord level, but will apply to Danish governance institutions more generally.

Institutional preconditions affecting implementability of the EPI – policy instruments: In Denmark there is a strong and widespread norm that drinking water should be untreated. Pure groundwater has evolved due to geological circumstances making it possible to use only groundwater (and not surface water) for drinking water. Thus, Danish drinking water is normally untreated, and if pesticide or nitrate limits are exceeded in a water supply, the well will normally be closed instead of treated. In other words, untreated drinking water has social and cultural value. This manifests itself also in a 30-year long regulatory effort to control pollution of water from both point sources and diffuse sources. Regulation of agricultural emissions has been a main focus in successive large-scale action plans to protect drinking water. Thus, in general there has been political will to regulate the use of nutrients and public support for these policies.

Moreover, the institutional climate for environmentally related taxes as a policy tool has also been favorable, as Denmark undertook a move towards a green tax reform in the 1990s, shifting the tax burden some from income taxes to environmentally related taxes a.o. (Ministry of Taxation, 2001). And as outlined above these taxes included taxes on agriculture, including a phosphorous tax of€0.53EUR/ kg P in feed and a pesticide tax varying from 33% to 54% on the sales price. The latter has just been revised to take into account the environmental and health impact of different pesticides. However, while these taxes indicate that agriculture is not exempt from environmental taxes, taxes have not been a significant tool in agricultural policy.

A tax on nitrogen in mineral fertilizer aiming to curb diffuse pollution would generally be compatible with the EU Common Agricultural Policy, especially as this policy is currently being revised with a greening of the first pillar as one of the objectives. A general tax on nitrogen applied to all farmers also complements the more targeted measures under the 2nd pillar of the CAP, the Rural Development Program which funds agro-environmental measures. However, revenue recycling may collide with EU state support rules under the EU treaty, which hold that a tax may not discriminate against foreign producers of certain goods, and if a tax is fully reimbursed to domestic producers this could constitute a trade barrier (Ministry of Taxation 2003). The recent reform of the Danish pesticide tax also included revenue recycling through the property tax, and this tax has received EU approval, indicating that a tax on mineral fertilizers may also pass this test.

A tax on mineral fertilizer would be compatible with most of the significant legislation in the field of agro-environmental regulation. Thus, overall it is aligned with the Water Framework Directive objective of ensuring to ensure good ecological quality of water and nitrate pollution is targeted specifically by the directive. Hence, a tax to reduce nitrate emissions is fully compatible with and supports implementation of the WFD.

As for nature conservation, the Habitats Directive (92/43/EEC) and the Birds Directive (79/409/EC) require that Member States to establish protection areas (bird directive) and special areas of conservation (Natura 2000, Habitats Directive) and to take requisite measures to protect flora and fauna. Fertilizer regulation is not specifically included in either of the directives, but to the extent that the use of fertilizers is counteractive to achieving the conservation objectives of these directives, regulation of the use of nitrogen and phosphorous might be considered among requisite measures. Likewise, fertilizer-extensive production methods in the conservation areas may be supported economically under the Common Agricultural Policy. Hence, measures to regulate fertilizer use under the habitats and bird directives would appear to be congruent with, possibly even reinforcing, nature conservation efforts. However, the nitrate tax might be a rather blunt – or cost-ineffective – instrument for this purpose, because as stated we expect it to be implemented equally across the country, not targeted to habitats.

Finally, the directives on renewable energy and on biofuels for transport both promote the use of renewable sources for energy production, including mandatory national targets. Moreover, it promotes the use of biofuels, e.g. based on ethanol, in transport. Thus, to the extent the energy policy offers economic incentives to production of energy crops, it will collide with a tax on nitrogen, possible rendering it ineffective.

As for national regulation, the main question concerns whether the nitrogen tax would be imposed as an add-on to the existing fertilizer regulations or would replace these. It is particularly important to analyze the relationship between the existing fertilizer quota and a tax on mineral fertilizer. Introducing the tax as an add-on to the quota would be less efficient, because it would reduce the flexibility of the EPI and therefore not necessarily achieve the full benefits of the economic instrument, particularly the reduction of social abatement costs. On the other hand, the quota ensures a cap on fertilizer usage which cannot be assured with a tax which allows farmers to use fertilizers if they are willing to pay. Recent empirical studies indicate that farmers are less responsive to economic incentives than modeled in ex ante evaluations which implies that a mineral fertilizer tax might not achieve reduction targets to the extent expected (Nielsen 2009; Pedersen et al., 2012). Other regulations including the requirements for handling of manure could work alongside a tax on mineral fertilizers. A tax on mineral fertilizers only could affect the balance between use of mineral fertilizer and manure, however. If mineral fertilizer is taxed the economic value of animal-produced fertilizers would increase, potentially leading to an increase in the use of animal production and usage of manure, which may lead to more leaching (Ministry of Taxation, 2003). On the other hand, harmonization rules impose restrictions on the number of livestock each farmer can have, based on the land holdings, and combined with the general rise in fertilizer prices, this would provide incentives for farmers to utilize the nitrogen in their livestock fertilizers more efficiently.

Institutional preconditions affecting implementability – policy processes and stakeholders: The decision making structure and the role of agricultural interest organizations may also condition implementability of a tax. Daugbjerg and Pedersen (2004) argue that the Danish agricultural policy network resembles a close-knit policy community consisting of producer interest organizations and the Ministry of Agriculture who share an interest in maintaining the competitive position of Danish agriculture in international trades. In such a policy community producer interests enjoy a privileged position, while other strong groups such as the Society for Nature Conservation operate more in the periphery or in other policy arenas. Daugbjerg and Pedersen (2004) show how this privileged position of farmers affected the designs of the pesticide tax both in 1995 and 1998. Thus, the pesticide tax adopted in the 1990s was designed so as to not diminish the international competitiveness of agriculture and so that revenues were reimbursed to agriculture (ibid: 234). Tax revenues were non-earmarked reimbursements to the sector, the solution preferred by farmers (ibid: 225). The recent remodeling of the pesticide tax also included reimbursement to farmers in the form of reduced property taxes, but also involved an increase in tax rates. Farmers have supported aspects of this tax because it is geared much more directly towards reducing use of pesticides with high environmental and health damage, but have also warned against a tax hurting the sector (Danish Agricultural Association). But by and large, agricultural associations have accepted the new pesticide tax. Thus, while these policy processes indicate the influence of agricultural associations on the policy process, they also suggest that revenue recycling improves acceptability, thus facilitating implementation of a tax.

Following the change of government in 2011, it is uncertain whether agriculture will maintain its privileged position in the policy making structure, but the current governmental agenda – shaped by the economic crisis - is geared towards economic growth and improving competitive conditions for Danish businesses. For instance, the recent growth policy package reduced energy taxes levied on businesses and aborted a planned tax on lorries (Regeringen, 2013). This raises questions as to the political interest in a fertilizer tax and at the very least suggests that a significant tax on fertilizers would also involve compensation to maintain profitability. As such the SCP20 scenario, including revenue recycling, might gain political acceptance, although a fertilizer tax has not received much attention during the policy discussions regarding implementation of the WFD.

Institutional capacity available: As stated, a tax similar to the proposed tax on nitrogen is currently in place for phosphorous, although levied on feed, as well as on pesticides. These taxes are administered and collected by the tax authorities. This means that there is an administrative structure in place to implement the fertilizer tax and collect the revenue.

Likewise, monitoring and inspection systems are already in place both for the current fertilizer quota system which relies on detailed fertilizer accounting, for the phosphorous tax and for the pesticide tax, all of which provide institutionalised knowledge, procedures and personnel that may also be applied toward monitoring of the nitrate tax.

Summarizing – changes in the governance framework? This section summarizes the analysis of implementability in order to assess whether changes in the governance framework are necessary for effective implementation of the modeled mineral fertilizer task.

The current normative and regulatory framework is fundamentally compatible with a fertilizer tax. The strong support for having untreated drinking water which has translated into significant acceptance in the general polity and public of regulating agricultural production suggests a low barrier to regulating nitrogen usage, and the widespread experience with environmentally related taxation could also pave the way for fertilizer tax. Moreover, these features mean that the proper institutional capacity and infrastructure is in place, making implementation relatively simple.

Furthermore, a tax on mineral fertilizer is generally compatible with the objectives of other policies that might interact with a fertilizer tax, including the Water Framework Directive and associated directives, suggesting a rather favorable legislative setting for implementation of the tax. However, the EU renewable energy and biofuels policies may have to be carefully reviewed and possibly amended to ensure that they do not offer incentives for more intensive agricultural production, including the use of mineral fertilizers, which would conflict with the incentive effect of a fertilizer tax. Moreover, the EU Treaty rules that a taxation system with revenue recycling may not favor domestic producers over importers could interfere with adoption of a fertilizer tax. As it is unlikely that this principle will be changed, the tax would have to be designed with this rule in mind, as has been done with the Danish pesticide tax.

Overall, this analysis suggests that no significant changes to the legislative framework are necessary, just as the institutional capacity is available. Regarding the policy making process, the traditionally privileged position of Danish agriculture in policy formulation may present an obstacle to implementation of the fertilizer tax. The views of agriculture on the fertilizer task as modeled have not yet been ascertained, but as even the SCP20 scenarios involve reduced profits, agricultural opposition is likely. Agriculture has opposed the river basin plans, challenging them in court both on procedural and substantial grounds (Landbrug og Fødevarer, 2013). On the other hand, agricultural interest organizations have collaborated on the design of the redesigned pesticide tax and essentially accepted this tax which may improve its implementation and ensure that farmers cooperate, reducing monitoring costs. Thus, while it is sometimes believed that diminishing the influence of agriculture on policy formulation would be a requirement for implementation of a mineral fertilizer tax, it is conceivable that incorporating interest organizations in the process will improve or at least not compromise implementation.

In summary, the broader institutional context is compatible with introduction of a fertilizer tax, but we would expect agriculture to try to lessen its economic impact. Overall, therefore, the analysis does not suggest the need for any changes in the normative or governance framework.

Uncertainty

Three factors lead to uncertainty regarding the modelled effect of the tax. Firstly, the tax design would most likely be subject to approval by EU to ensure compliance with EU rules that prohibit discriminatory tax systems that might indirectly favour domestic producers due to revenue recycling.

Secondly, several studies indicate that farmers can be less responsive to economic incentives than modelled in optimization models. Thus, Nielsen (2009) and Pedersen et al. (2012) have shown that a sizable proportion of farmers are driven as much by professional ambitions to produce a good crop as by profit, hence, they attempt to optimize their physical yield rather than their economic yield. This would lead to higher fertilizer levels than economically optimal. Yet, in this case the economic pressure that farmers are under may work in favor of the effectiveness of the tax, as behavioral economics have shown that companies are more likely to pay attention to costs and profit when circumstances push them do so (Cyert and March, 1952; Leibenstein, 1966).

The third source of uncertainty relates to the role of interest organizations in the policy making phase, specifically whether agricultural interests might succeed in negotiating a design that will reduce the economic incentive and therefore also the effectiveness of the tax scheme.

8 Conclusions and policy recommendations

Contributions from economic policy instruments have been largely ignored during the recent river basin management planning process in Denmark that has focused on land-use specific measures, many of which are involving publicly financed support schemes.

In this case study we have explored ex-ante scenarios for two EPI's and what they might contribute towards the river basin management planning targets for Odense River Basin (ORB), in particular with regard to water quality. Our methodology is based on availability of catchment specific data and analysis of behavioral responses to regulatory efforts and measures of pricing. We have done so in accordance with the assessment framework developed for all EPI-WATER case studies.

Per capita water use in Odense has dropped with 40% over the past 20 years which helps increase water flows in Odense river and in the smaller adjoining water courses too. It also implies lower nitrogen concentrations in Odense river, water courses and Fjord due to higher groundwater fluxes.

Our analysis indicates that Odense river water flows were 2% lower before introduction of the Water Supply Tax. Regression analysis suggests that the tax can explain directly only 0.1-0.3% of the change. When taking into account the entire scheme of full-cost water pricing to households, its impact may amount to somewhere between 0.5% and 1.5% of the change in Odense river water volume. Hereby it is reducing flows to sewage treatment plants with 1-2 million m^3 and the resulting potential relief on discharges can amount to 6-12 tN annually.

The impact of the pricing approach on water quantity is far more significant in smaller watercourses close to abstractions. Simulations for Holmehave sub-catchment indicate that water flows in the smaller watercourse was 12% less before the full-cost water pricing scheme. While the Water Supply Tax can explain 1-2% of this change, depending on the regression model, the full-cost water pricing scheme as a whole is likely to be accounting for 5-10%.

Future scenarios have been modeled to take into account projections for population growth and increases in economic activities. These projections suggest that the Water Supply Tax will need to be increased to keep household water demand in check, considering that there is very little space for increasing water abstraction without implications for water flows in ORB water courses. The 'Economy First' scenario, with 2% annual economic growth and a population increasing in line with forecasts from Statistics Denmark, suggests water flows in Odense river will reduce with 6%. The simulations presented here indicate that the Water Supply Tax may have to be doubled to reduce water consumption per household and maintain the overall balance in ORB, allowing for stable water flows. Higher precipitation as a result of climate change may influence these implications however.

Water demand has become less inelastic in tandem with water price increases and for a household sector where apartment blocks are largely without water meters, it can be hypothesized that extending metering would yield additional water savings with associated reliefs on N-flows.

The use of mineral fertilizers on arable land has been considerably reduced from its peak in the mid-1980's, dropping from 145 kg N/ha in 1984 to 71 kgN/ha in 2012 (Statistics Denmark, 2013).

We have introduced two EPI scenarios and explored their implications for nitrogen flows. The tax rates for the EPI-scenarios in question amount to €1.85 (T1) and €4.54 (T2) per kg N in mineral fertilizers.

While our T2 rate proves to be practically prohibitive to the use of mineral fertilizers, our lower T1 rate helps reduce their use by more than 50%. We have found that T2 could help accomplish a

Fjord classification of 'high' ecological quality, whereas T1 would be sufficient to meet the stipulated river basin management planning classification of 'good' ecological quality for Odense Fjord. We have found considerable monetary benefits for both scenarios ranging from €4.8 to €7.6 million annually, despite a relatively timid valuation approach focusing mainly on use values.

With T2 there is no tax revenue available for compensating farmers and as a result T2 becomes rather costly, about €12 million/year. In contrast the cost of T1 to farmers, according to the ORB area model, is estimated to be €4.1 million annually, which compares favorably with benefits of €4.8 million.

With T1 the nitrogen transported to Odense Fjord would be reduced with more than 600 tons from the present level. The aggregate cost of accomplishing a comparable reduction with non-EPI measures has previously been estimated at €5.8 million annually (MOE, 2007:70), 40 per cent more than with T1.

The main reason for the superiority of economic instruments is that they provide sound incentives for all polluters to search for the most efficient abatement options.

In the ORB-model 2000 farms have been modeled individually to optimize their yield functions for crops according to the cost of Nitrogen-fertilizer, while remaining within the boundaries for crop diversity related to their basic specialization. The options that the model can identify for farmers come out favorably economically as compared to the changes in land use that can be envisaged by a 'central planner'. By recycling revenues for a lowering of land use taxation, the scheme will not impose an additional tax burden on farmers. The scheme will induce a net loss in income that according to our findings can be compensated at less cost than with a land-use regulation oriented approach.

The main challenge with nitrogen taxation is that its specific design may affect agricultural subsectors differently. A tax only on mineral fertilizer-N will penalise crop growing and provide a wind-fall profit to livestock farmers, who will be able to dispose of organic fertilizers (such as manure) as a tradable good. In the current situation organic fertilizer is to some extent a waste product, despite major efforts to improve its utilisation. Recycling revenues from a mineral fertilizer-N tax to reduce land use taxation for farmland will help partly compensate crop growers. There would also be macro-economic benefits, as imported fertilizers are substituted with a domestic resource.

More sophisticated models of N-loss taxation could provide more fairness, in that each farmer would face a tax burden in accordance with the specific environmental burdens associated with activity. Taxing N-input of both fodder and fertilizers, while providing a refund for N in products, has been deemed administratively feasible in previous analysis (MOT, 2003). N-loss taxation would also generate revenue that can be recycled to offset negative macro-economic effects (Hansen, 1999). It is a far more complicated scheme than a tax on fertilizer-N and hence may pose more challenges from an implementability point of view.

The present analysis shows that a Water Supply Tax (EPI1) only provides a tiny contribution to improving water quality, whereas a Nitrogen-tax (EPI2) has potential to accomplish the

stipulated river basin management planning targets for Odense Fjord in an economically attractive way.

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Annex I: Projections (EPI1)

Future projections for several physical and economic variables estimated in the ex-ante assessment of EPI1. Acronyms: *ORB*, Odense River Basin; *WS*, Water use (consumption or demand); *h*, Households; *e*, Estimated; *PC*, Per capita (water use); *POP*, Population; *T1-2*, Tax model 1-2; *M1-2*, Elasticity model 1-2.

	Scenario	2015	2020	2025	2030
POP ORB	EcF	251188	260061	270270	280092
	FoE	244317	243365	240616	237126
	PoR	246853	250546	254129	257178
	SuE	247158	251628	256338	260807
WS (m3)	EcF	24378707	26277887	28177068	31041628
	FoE	20025769	20473970	20922171	21424138
	PoR	18854802	18912681	18970559	19029335
	SuE	18534840	18486064	18437289	18389150
ehWS (m3)	EcF	14229484	15338007	16446530	18118531
	FoE	11688740	11950348	12211956	12504947
	PoR	11005264	11039047	11072830	11107136
	SuE	10818507	10790037	10761568	10733470
ehPC (m3/person)	EcF	57.0	59.4	61.3	65.1
	FoE	47.8	49.1	50.8	52.7
	PoR	44.6	44.1	43.6	43.2
	SuE	43.8	42.9	42.0	41.2
Future Tax (dkk)	T1 (25% / 10 y)	6.3	7.8	7.8	9.8
	T2 (30% / 10 y)	6.5	8.5	8.5	11.0
Δ-Tax (dkk)	T1 (25% / 10 y)	1.3	2.8	2.8	4.8
	T2 (30% / 10 y)	1.5	3.5	3.5	6.0
Δ-ehPC (M1, elasticity= -0.366)	T1 (25% / 10 y)	-0.5	-1.0	-1.0	-1.7
	T2 (30% / 10 y)	-0.5	-1.3	-1.3	-2.2
Δ-ehPC (M2, elasticity= -0.287)	T1 (25% / 10 y)	-0.4	-0.8	-0.8	-1.4
	T2 (30% / 10 y)	-0.4	-1.0	-1.0	-1.7
Reduced ehPC (m3/person) T1M1	EcF	56.6	58.4	60.3	63.4
	FoE	47.4	48.1	49.7	51.0
	PoR	44.1	43.0	42.5	41.4
	SuE	43.3	41.9	41.0	39.4
Reduced ehPC (m3/person) T1M2	EcF	56.5	58.2	60.0	62.9
	FoE	47.3	47.8	49.5	50.5
	PoR	44.0	42.8	42.3	41.0
	SuE	43.2	41.6	40.7	39.0
Reduced ehPC (m3/person) T2M1	EcF	56.7	58.6	60.5	63.7

	FoE	47.5	48.3	49.9	51.4
	PoR	44.2	43.3	42.8	41.8
	SuE	43.4	42.1	41.2	39.8
Reduced ehPC (m3/person) T2M2	EcF	56.6	58.5	60.3	63.4
	FoE	47.4	48.1	49.8	51.0
	PoR	44.2	43.1	42.6	41.5
	SuE	43.3	41.9	41.0	39.4
Reduced ehWS (m3) T1M1	EcF	14115187	15072046	16170005	17632417
	FoE	11576809	11699485	11963927	12090770
	PoR	10892171	10780781	10810871	10657935
	SuE	10705275	10530657	10497332	10277930
Reduced ehWS (m3) T2M1	EcF	14092328	15011761	16107326	17508036
	FoE	11554422	11642622	11907707	11984795
	PoR	10869553	10722241	10751493	10542998
	SuE	10682628	10471864	10437438	10161372
Reduced ehWS (m3) T1M2	EcF	14139983	15129743	16229994	17737875
	FoE	11601091	11753907	12017734	12180621
	PoR	10916706	10836809	10867700	10755385
	SuE	10729839	10586927	10554655	10376755
Reduced ehWS (m3) T2M2	EcF	14122082	15082537	16180913	17640477
	FoE	11583561	11709380	11973711	12097637
	PoR	10898994	10790969	10821204	10665382
	SuE	10712106	10540888	10507755	10285483
Water savings (m3) T1M1	EcF	114297	265961	276525	486114
	FoE	111931	250863	248029	414177
	PoR	113093	258266	261959	449201
	SuE	113232	259381	264236	455540
water savings (m3) T2M1	EcF	137157	326246	339204	610495
	FoE	134317	307725	304249	520152
	PoR	135711	316806	321337	564138
	SuE	135879	318174	324130	572098
water savings (m3) T1M2	EcF	89502	208264	216536	380657
	FoE	87649	196441	194222	324326
	PoR	88559	202238	205130	351752
	SuE	88668	203111	206913	356715
water savings (m3) T2M2	EcF	107402	255470	265617	478055
	FoE	105179	240968	238246	407310
	PoR	106270	248079	251626	441754
	SuE	106401	249149	253813	447987
Reduced WS (m3) T1M1	EcF	24264410	26011926	27900543	30555514
	FoE	19913838	20223107	20674141	21009961
	PoR	18741709	18654415	18708600	18580134
	SuE	18421607	18226683	18173053	17933610

Reduced WS (m3) T2M1	EcF	24241550	25951641	27837863	30431133
	FoE	19891451	20166244	20617921	20903986
	PoR	18719091	18595874	18649223	18465197
	SuE	18398961	18167890	18113159	17817052
Reduced WS (m3) T1M2	EcF	24289205	26069623	27960532	30660972
	FoE	19938120	20277529	20727949	21099813
	PoR	18766243	18710443	18765429	18677583
	SuE	18446172	18282953	18230376	18032435
Reduced WS (m3) T2M2	EcF	24271305	26022417	27911450	30563574
	FoE	19920590	20233002	20683925	21016828
	PoR	18748532	18664602	18718933	18587581
	SuE	18428438	18236915	18183476	17941163

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Annex III: Supplementary material

The following documents have been produced as a contribution to the Water Quality case study. They are accessible from the project's web site (www.epi-water.eu).

Skou Andersen, M., and Pizzol, M. (2012). Description of the Odense case study. Output no.1 of the Research Task 4.4 of the EPI-WATER project. Published in the EPI-WATER WP4 progress report: Intermediate Case studies, December 20th, Aarhus University, Denmark.

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